PHOTOGRAPHY TO-DAY

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PHOTOGRAPHY TO-DAY

BY

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CHAPTER I

INTRODUCTION

PHOTOGRAPHY in the sense that we now understand the term —namely, the art of recording images of natural objects by the action of light on sensitive substances—is little more than a hundred years old.

That light could be made to cast an image by admitting it into a darkened room through a small aperture or a lens had been known since 1568, and the camera obscura, in which this image was projected on to a ground glass or white screen, was in use in 1589. In 1833 Fox Talbot, who had been disappointed in the results of his attempts to use the camera obscura as an aid to sketching, determined to find some means of making the image into a permanent record by its action on a light-sensitive substance.

'How charming it would be', he wrote, 'if it were possible to cause these natural images to print themselves durably and remain fixed upon paper. And why should it not be possible, I asked myself. The picture, divested of the ideas which accompany it and considered in its ultimate nature, is but a succession of stronger lights thrown upon one part of the paper, and deeper shadows on another. Now light can exert an action and in certain circumstances does exert one sufficient to cause changes in material bodies. Suppose then, an action could be exerted on to paper; and suppose the paper could be visibly changed by it. In that case surely some effect must result having a general resemblance to the cause which produced it, so that the variegated scene of light and shade might leave its image or impression behind, stronger or weaker, on different parts of the paper according to the strength or weakness of the light which had acted there.'

Nearly every substance undergoes some change in the presence of light, and examples in which the change was visible—the tanning of skin, the bleaching of Tyrean purple, and so on—had been known and commented on since ancient times. Schultz had remarked that silver salts darkened in sunlight, and in 1727 the outlines of opaque objects of distinctive shape, such as lace, had been recorded by laying them on paper brushed over with such salts and exposing

to daylight. The silhouettes so obtained were not permanent because no means had been discovered of dissolving away the unchanged silver salts or of preventing these from further darkening.

In 1837 Fox Talbot placed a sheet of paper washed over with silver nitrate in the place of the focussing screen of his camera obscura, and after an exposure of some hours he obtained a recognizable picture of his home—Lacock Abbey—which he rendered semi-permanent by bathing the paper in a solution of common salt.

A few years later Herschel showed that sodium thiosulphate, which he had discovered in 1819, would dissolve away the unaltered silver salts, leaving the darkened product of light action untouched. Under the name 'hypo', this salt is still in universal use for this purpose.

Meanwhile Daguerre had discovered that an exposure to light insufficient to produce a visible image nevertheless resulted in a change in the silver salts with which he was experimenting. Daguerre made his light-sensitive material by exposing sheets of silver to iodine vapour, when the iodine attacked the silver surface, giving a superficial coating of silver iodide. The pale yellow layer of silver iodide darkened under the action of light owing to the liberation of black metallic silver from the compound, and on removal from the camera, therefore, an image of the scene being photographed would be visible on the plate if the exposure had been sufficiently prolonged. It is said that Daguerre placed such a plate, which he thought he had spoiled by under-exposure, in a dark cupboard containing an unstoppered bottle of mercury, and when he removed the plate some time later he was startled to find on its surface an excellent image of the subject he had photographed. It appeared that the invisibly small deposit of metallic silver produced as a result of light action had the power of amalgamating with the mercury vapour, and so increasing to a visible size, in much the same way as, by breathing on a glass tumbler which has been handled, the invisible deposits of grease left by the cleanest fingers can be 'developed' to visibility owing to the local deposition of water droplets.

About the same time Fox Talbot discovered that the almost invisible silver image produced by short exposures on silver iodide could also be developed by 'silver plating' them—a solution of silver nitrate and gallic acid depositing

silver preferentially on the exposed portions of his pictures. Talbot went on to show that the 'negative' image produced by light action and subsequent development could be printed upon similar material to give a positive in which the gradations of light and shade resembled those of nature.

The foundations of present-day photography were laid at this point, and the spectacular advance, from an individual craft in which the isolated enthusiast did everything for himself to a highly organized industry, commenced.

Each succeeding decade saw the ramifications of photography spreading farther and farther into the inner recesses of our daily lives. The discovery that celluloid made an excellent support for the light-sensitive compounds brought the vast bulk of present-day amateurs to an interest in photography as a hobby. The film camera became simpler and cheaper—evolving from a complicated box of tricks so intricate that it had to be returned to the makers every time the film required changing, to a wide range of admirable instruments whose chief fault is that their simplicity of operation encourages the off-hand thoughtlessness with which their existence is accepted.

Amateurs have played a great part in the history of photography, though it must be confessed that nine-tenths of the present-day so-called 'amateur photographers' are simply 'button pressers', who know practically nothing of the wonderful tool they are handling. These people 'let off' their cameras much as one 'lets off' a firework—trusting hopefully that the result will be beautiful, if not surprising. Whereas, however, the result of applying a match to a firework is a foregone, if unknown, conclusion whose nature was determined by its manufacturer, there is no step in the photographic process from the first consideration of the scene to its final trapping on paper that does not have some bearing on the final result—the picture. With an understanding of these steps comes ability to control their influence, and the consequent thrill of handling the camera with the knowledge of how best to attain a result which is preconceived rather than accidental—the power of producing pictures, which are a means of self-expression or accurate record rather than black-and-white platitudes.

It is the difference between being a passenger in a car whose windows are blurred with rain and driving the car yourself with the wind-screen wiper working.

Celluloid also made the kinema industry possible, and this in turn grew until it has become the third largest industry in the U.S.A., whilst in England the production of kine-films is measured in thousands of miles per week.

But the contributions to human entertainment by the snapshot and kine cameras are fundamentally of less importance to human welfare than the contributions photography is making to medicine, scientific research, and industry. It is true that its assistance is bestowed indiscriminately—it shows the armament manufacturer unsuspected flaws in his shells, the speed at which they travel, and what happens inside the gun barrel when they are fired, and so helps him to improve the efficiency of his weapon and the accuracy of his aim. At the same time, by, in effect, photographing the sound wave from the discharge from two or three different points, it enables the other side to determine the precise position of the gun within a few minutes of the first shot—the same instruments going on to tell whether the counter-shelling which follows is on its target. And then, when the shell has been fired and the gun has in consequence been located and destroyed, X-ray photography makes the surgeon's task easier by showing him the precise situation of the fragments of shell or gun embedded in the bodies of the wounded men!

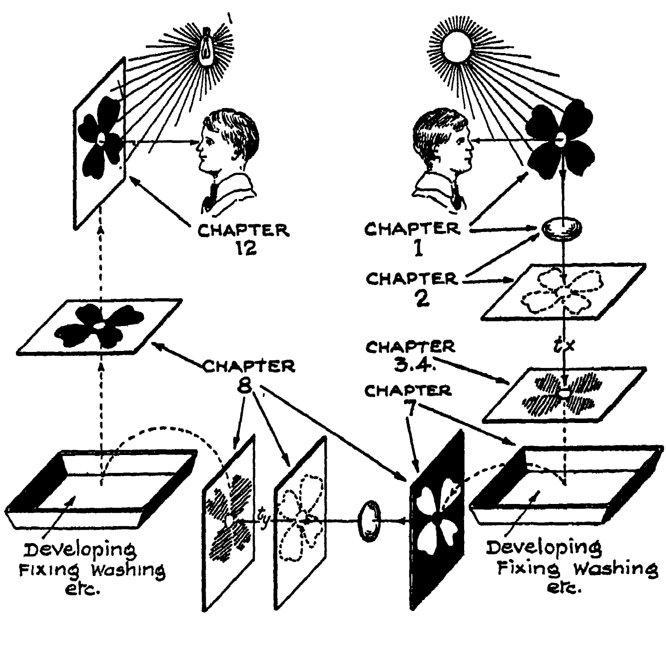
Meanwhile, photography in other hands is doing its best to demonstrate the futility, anyway, of using guns to settle international differences of opinion. In the form of 'still' photographs and kine-film, every country is rapidly accumulating records of the vanishing past and busy present. International organizations are gradually coming into existence for the preservation and mutual exchange of kine-films of permanent value and the contributions these organizations are already making towards a better understanding between peoples are of inestimable service to civilization.

So vast, indeed, has the subject of photography become that even if it succeeds in its purpose, a book of this size can do little more than whet the appetite of the reader, and, on the assumption that it will succeed in this purpose, a bibliography of representative text-books is given as an appendix.

Since the present volume is not intended to be a text-book, detailed instructions for handling and processing plates, films, and papers, which will be found in practical manuals

or on the leaflets issued by the manufacturers, have been omitted. Such practical aspects of the straightforward photographic process as are given relate to matters which, though important, are rarely dealt with adequately in the cheaper text-books. The question of exposure, for example, although the crux of the photographic process, is too often shirked in the more elementary books, or dismissed with a few 'rule-of-thumb' instructions. Some account of the factors involved in determining exposure, and a warning that exposure meters, however expensive, will not entirely eliminate the possibility of error, as many manufacturer's advertisements would lead one to believe, is only due to an intelligent reader.

Finally, since this chapter has somehow turned itself into a semi-apologetic preface, the writer may as well conclude it by saying that he finds some comfort for the sketchiness of certain portions of the book in the words of Voltaire: 'Woe to the author who wishes always to instruct! The secret of boring is the attempt to say everything.'



CHAPTER II

LIGHT AND LENSES

THE simplest way of producing a photographic image is to admit light into a dark chamber through a pin-hole. For certain types of photograph this primitive arrangement is as suitable as the complex system of carefully worked glasses which constitutes a modern lens.

The manner in which images are produced by a pin-hole is shown in Fig. 1, in which *A* represents a thin sheet of

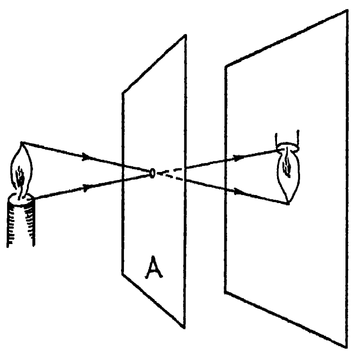


FIG. 1

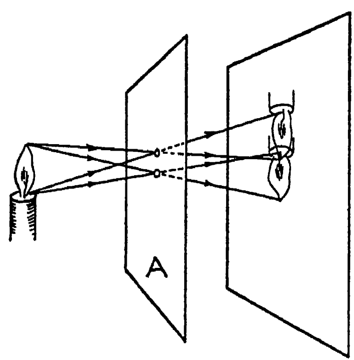
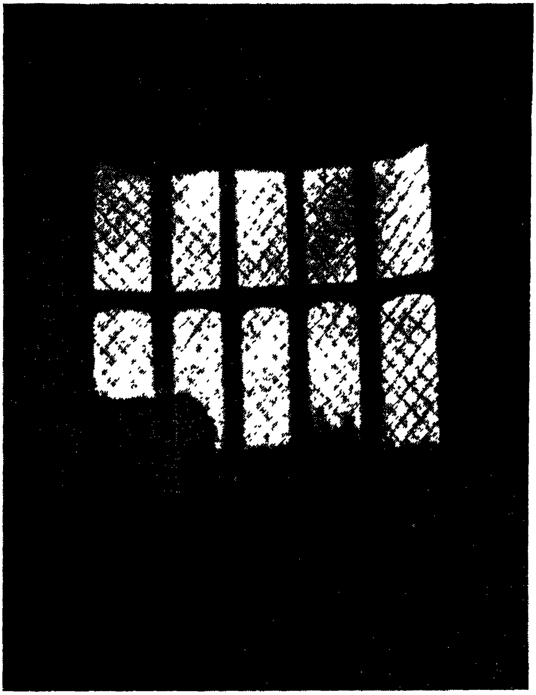


FIG. 2

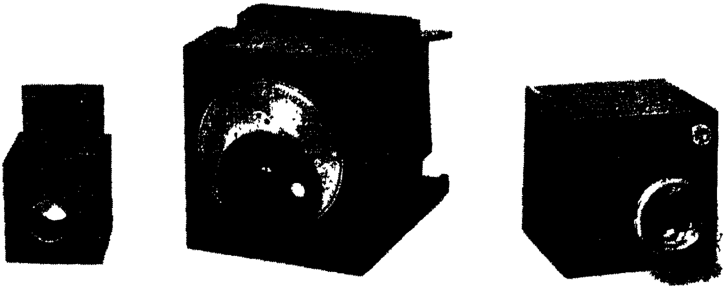
cardboard with a pin-hole in the middle, held between a candle flame and a sheet of white paper. Every point on the candle flame is radiating light in all directions, but from each point only those rays of light proceeding directly from the flame through the pin-hole will fall upon the white paper screen, and the combination of innumerable such points of light builds up the image we see.

The image will be dull, because very little light can get through the pin-hole. If we enlarge the hole, more light will reach the screen, but from every point of the candle flame a wider bundle of light rays will pass through the hole. Light from any particular point will therefore be spread over a larger area of the screen, and the image will no longer be sharp. To avoid this drawback, we might make a second pin-hole close to the first. Twice the original amount of light will reach the screen, but two images will be produced (Fig. 2), and to make them lie exactly on



A reproduction of the earliest existing photograph. A window in Lacock Abbey photographed by H. Fox Talbot in 1835

Herbert Lambert Collection



Early cameras used by Fox Talbot. The smallest measured 2 in. × 2¼ in.

Photo.: Science Museum

Snow roofs, Andermatt

Courtesy of J. Dudley Johnston, Hon. F.R.P.S.

top of one another, which is the only condition in which the image will be twice as bright and yet sharp, it is necessary to bend the rays of light. There is an easy way of accomplishing this. When a ray of light travelling through air enters a piece of glass at an angle, the ray is bent so that it penetrates the glass more steeply than it enters, that is to say, it is bent away from the surface. On leaving the glass the ray suffers a second bending equal in extent to the first, but this time towards the surface it is leaving. Fig. 3 shows how, by putting two wedge-shaped pieces of glass (called prisms) behind the two pin-holes, we can make use of

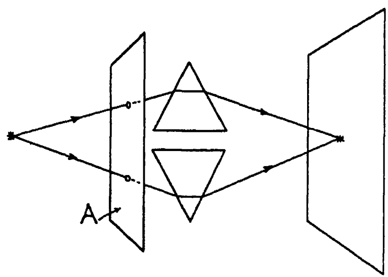


FIG. 3

this phenomenon to cause the two images to coincide, giving us therefore a sharp image which is twice as bright as that obtained through a single pin-hole.

If we could increase the number of pin-holes and prisms indefinitely, until in fact the prisms formed a solid mass of glass with a continuously curved surface, and the pin-holes were so numerous that there was no cardboard left to separate them one from another, we should have a large hole, and behind it a lens! (Fig. 4.)

Since all the rays of light that pass through the lens go to form one image, this will be many times brighter than the original pin-hole image, but it will only be sharply defined when the viewing screen is at such a distance from the lens that all the rays of light coming from any particular point on the subject meet again as a result of the bending they have suffered in passing through the glass. If the viewing screen is placed nearer to or farther from the lens the image will be 'blurred', or, to use the accepted term, 'out of focus'.

The more distant objects are, the nearer to the lens must

the viewing screen be placed for sharp focus, until a point is reached when the objects are so far away from the lens that the rays of light proceeding therefrom are for all practical purposes parallel and come to a focus in one plane. When this is so, the distance between the viewing screen and the centre of the lens is called the *focal length* of the lens.

Let us suppose that, armed with the knowledge so far acquired, we attempt to build a camera. The pin-hole

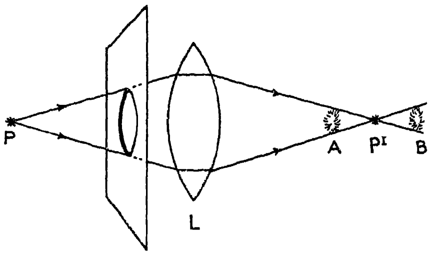


FIG. 4

Light from the point P comes to a sharp focus only at P^1. If the screen is advanced towards A or withdrawn towards B the image of the point is spread over a larger area and is therefore no longer a point. When P is very distant the distance LP^1 is called the focal length of the lens.

variety will not present much difficulty, and excellent work can be done with very simply made apparatus (Fig. 5).

A hole a quarter of an inch in diameter is made in the bottom of an ordinary 2-inch cardboard pill-box. The pill-box is blackened on the inside, and a sheet of very thin black opaque paper coated with gum is placed over the hole. When the gum is dry, the black paper will be taut, and a tiny hole is made in the centre by touching the surface with the red-hot point of a no. 10 sewing needle. When the needle has cooled it is used to enlarge the hole until it will just pass through.

Place the lid of the pill-box in the centre of one end of a light-tight box (6 to 8 inches long), and with a piece of pencil outline its edge on the box. In the centre of the circle so drawn drill a half-inch hole, and then cement the bottom of the pill-box to this end, keeping it within the confines of the circle. Four brass pins are pushed into the woodwork of the end opposite the pin-hole, and their heads bent over at right angles so that, in the dark, a photographic plate

can be placed in position opposite the pin-hole. When the plate has been fastened into position, with the box closed and the lid on the pill-box, the camera can be taken from the dark room to the scene of the photograph. If there is any doubt about the light-tightness of the box, it will be as well to wrap the whole affair in a dark cloth, merely leaving the lid of the pill-box exposed, but with a well-made box whose joints have all been covered with electrical engineers' black tape this precaution will be unnecessary, and it will be easier to ensure that the camera remains absolutely stationary during the long exposure which will be necessary.

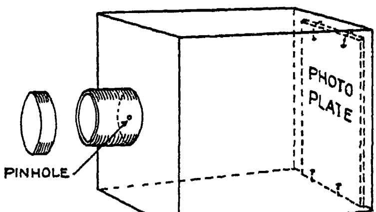


FIG. 5

If we assume that this first photograph is taken from the window-sill of a room overlooking a busy street, an exposure of from fifteen to thirty minutes will probably be required, and this is given by uncapping the pill-box for such a period.

When the plate is developed, and assuming that the exposure has been of the right order, it will be found that we have a perfectly sharp photograph of an empty street! The moving traffic has not remained in any position long enough to be recorded on the plate, and when one wants to secure photographs of buildings unobscured by passing traffic, the pin-hole camera has much to recommend it.

Another advantage of the pin-hole is the wide angle of view which it will embrace, and in meteorology this advantage is turned to account when recording the distribution of sunlight and daylight over the sky. A cylindrical camera is used, with a pin-hole in the middle of one end of the cylinder, a photographic film being fitted round the inside curve of the cylinder. With such a camera it is possible to photograph the whole of the visible sky at one exposure—a course impossible with a lens camera owing to angular limitations and the impossibility of getting sufficient light to the edges of the picture while preserving accurate focussing. However, the prolonged exposures which are required severely limit the applications of a pin-hole camera, and to attempt to make a lens camera is hardly worth while for

reasons which will become obvious if we consider what will happen if we do.

Suppose that, following up our first investigations, we enlarge the pin-hole considerably and fit a convex lens into the front of the pill-box. As already explained, the photographic plate will now have to be placed in a definite position, depending on the distance of the subject, if we are to obtain a sharp image, and to determine what this position is to be it will be necessary to modify the camera so that the distance between the plate and the lens can be varied. This could be accomplished by cutting the camera in half and linking the back and front with collapsible, light-tight bellows. Moreover, in order to determine just where to put the plate in order that it shall receive a sharp image of the chosen subject, we must first focus the image on a ground-glass viewing screen, and then substitute the plate for this viewing screen before making the exposure. We must therefore have the plate in some form of light-tight container, such as a shallow box closed by a withdrawable sheath, called a dark-slide, which will enable us to replace the viewing screen by the plate without having to remove the apparatus to the dark-room.

It is already obvious that making such a camera is a very different proposition from building the pin-hole model; but having got as far as this, we shall find that, with a simple converging lens, the image on the viewing screen will not be entirely satisfactory. The image will be visibly distorted, particularly at the edges. The upright lines of the buildings in the street will be bent inwards towards the middle of the field of view, and the brightness of the image will fall off as it approaches the edge of the screen (Plate 47). Moreover, when the image in the centre is focussed sharply, that at the edges will be ill defined and will probably show coloured fringes. If, however, disregarding these failings, we focus as critically as possible on a subject whose image falls in the centre of the screen, and then, substituting a photographic plate for the screen, we make an exposure, it will be found on development that the picture is not sharp, having nowhere the critical definition we obtained on the ground glass. In fact, the best result we shall get will compare very unfavourably with that produced by the cheapest of commercial cameras.

The qualities of a lens which are responsible for the

imperfection of the result we have obtained are called 'aberrations', and in a modern photo lens they have been reduced to negligible proportions by a variety of expedients.

For example, the image in the centre of the ground glass is sharp when its edges are ill defined, and vice versa, because the degree to which the rays of light are bent (or refracted) depends on the thickness of the glass, and since a convex lens is of necessity thicker in the middle than at the edges, the rays passing through the edges come to a focus nearer to the lens than those passing through the middle. This aberration can be partially cured by contracting the opening in front of the lens by a diaphragm or 'stop', so that only those rays passing through the central portion of the lens are used to form an image. Since, however, the main reason for employing a lens at all is the relatively large amount of light which can be used to form the image, the use of a sufficiently small stop would be a retrograde step. Moreover, the distortion of straight lines which occur at the edges of the image field would still be present. A pair of upright columns will appear 'bow-legged' if we put a stop in front of the lens and 'knock-kneed' if we put it behind the lens (Plate 47). The cure is to use two lenses and put the stop between the two, when the 'curvilinear distortion' due to one lens is exactly cancelled by the other. Such a lens is known as a rectilinear, and this method of correcting aberrations by the use of two lenses whose aberrations, being of opposite type, cancel each other out, is one of the most valuable methods available for reducing them to negligible proportions.

Although by the use of two lenses with a diaphragm between, or by the use of a lens of meniscus form, we can partially overcome most of the visible defects in our ground-glass image, the difficulty that when we have critically focussed this image the resulting negative exposed in the same plane is not sharp still remains, and to understand why this is the case it is necessary to know something of the nature of light.

Hooke, in his *Micrographia* (1664), wrote: 'Light consists of very minute vibrating movements of an elastic medium, which is propagated with great rapidity, but not instantaneously, in straight lines that proceed like the radii of a sphere from a central point common to all.'

We can convert this into a modern definition by inserting

the words 'behaves as if it were' after the word 'light', since we are not at all sure nowadays that the 'elastic medium' postulated by Hooke and usually termed the ether has in fact any physical existence, and for our present purposes it will be sufficient if we think of light as a wave motion without stopping to consider what it is that is moving.

We do not need to understand the nature of water in order to study some of the effects of throwing a stone into a still pond. When we do this we notice that a series of wavelets starts at the point where the stone fell and spreads in ever-widening circles consisting of crests and troughs. The distance between the crest of each wave is known as the wave-length; and one of the curious things about a wave is that once it has been created its wave-length remains unalterably fixed however far the wave may travel. If a cork is floating on the pond we shall notice that it rides up and down as first the crest and then the trough of each wavelet passes over the point where it is stationed. By means of waves we have transferred energy from the stone to the cork.

Radio has familiarized most people with such conceptions —the transference of energy through space by means of electro-magnetic waves of constant wave-length travelling in ever-expanding spheres from the source. Light is a manifestation of precisely similar nature—the only fundamental difference between a radio wave and a light wave being in the dimensions of the waves. Whereas radio waves vary from a few metres (Empire broadcasting 30 metres) to several hundred metres (Daventry 5XX 1,500 metres), visible light is a heterogeneous collection of vibrations of wave-lengths ranging from 1/2,500,000th to 1/1,400,000th of a metre. Such very short electro-magnetic waves are usually measured in ten-millionths of a millimetre, the so-called Ångstrom Unit, and this notation gives 4,000 Å.U. to 7,000 Å.U. as the range of wave-lengths whose mixture arouses in the eye the sensation of sight.

The properties of electro-magnetic waves vary with their wave-length, and between the relatively long waves used in broadcasting and the shortest waves that can be detected lie waves whose characteristic properties have justified their receiving distinctive names—'X-rays', which penetrate the less dense form of matter, 'chemical rays', and 'ultra-violet rays', which promote chemical changes in substances, 'light', by which we see, and finally the 'infra red' and heat rays.

Wave-lengths in Ångstrom units

X-rays	0.1 Å.U.–1.0 Å.U.
Ultra-violet	100 Å.U.–4,000 Å.U.
Visible	4,000 Å.U.–8,000 Å.U.
Infra red (photographable)	8,000 Å.U.–10,000 Å.U.
Infra red (heat)	10,000 Å.U.–1,000,000 Å.U.
Hertzian (radio)	1 mm.–15,000 kilometres

The distinctive properties of any group merge by imperceptible degrees into those of its neighbours, and if we analyse a group into its constituent rays we can often detect a gradual change in the effects produced over quite small alterations in wave-lengths.

When white light is analysed into its components it is found that vibrations having different wave-lengths affect the perceptive mechanism of our eyes in different ways, and we call these different sensations 'colours'.

One way of analysing white light into its component colours is to pass it through a prism, when it is not only bent as already indicated, but spread out into a band of coloured light—arranged in the familiar rainbow order, and called the 'spectrum'. The beam of white light is dispersed into its constituent rays because different wave-lengths are differently bent as they pass through the prism. The violet rays, which are nearest in wave-length to the 'chemical rays', are bent most, and the red ones least. It will also be found that the photographic activity of the different rays differs, for if a piece of printing-out paper is placed in the spectrum it will darken rapidly in the violet-blue section and hardly at all in the green, yellow, or red. Moreover, close examination will show that the greatest darkening occurs in the extreme violet, where the rays passing through the prism are hardly visible as light at all.

If we now return to a consideration of our single-lens camera we can explain why it was that our critically focussed image did not give a sharply defined picture. We have seen that the lens may be considered as being built up of prisms and each prism is not only bending light rays to a focus, but it is also dispersing them. We have already noticed one indication of this dispersion in the troublesome coloured fringes on the image at the edge of our ground class screen, and an examination of Fig. 6 shows how the rays which are the most active photographically come to a focus at a point nearer to the lens than the visually brighter yellowish rays by which we focussed.

To overcome this chromatic aberration, as it is called, and bring the visually bright and chemically active rays to the same focus, use is made of the knowledge that the dispersed rays can be recombined by passing them back through the prism along their track, and Dolland, an English optician, showed in 1752 that by combining two lenses of different shape made of glasses of different dispersing powers, it was possible to arrange for the dispersed rays emerging from one glass to be recombined on passing through the second glass, so that the rays were bent as required, but the dispersion was cancelled. Such a lens is called 'achromatic'.

The method of correcting lens aberrations by using in conjunction different types of glass with different refractive and

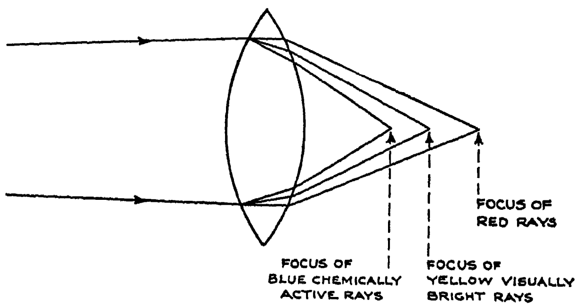


FIG. 6

dispersing powers is one of the most important inventions in optics, but the conditions which must be fulfilled to bring the chemical and visual rays into focus are different from those which ensure that the field is flat, and a good lens is really the best compromise that can be attained between mutually contradictory requirements. When this nicely balanced mixture of opposing faults gives an image which is critically sharp right to the edge of the field and has at the same time identical visual and chemical focus, it is called an 'anastigmat'.

It must not be thought, however, that successful photography demands that an anastigmat be employed. The ordinary fixed-focus film camera with which 90 per cent. of amateurs make their pictures have simple meniscus lenses in which a fairly small stop eliminates undue curvature of the field whilst yet permitting snapshots in good light, while the lens is fixed by the manufacturers at such a distance in front of the film that the chemically active rays are sharply focussed on the film for all distances beyond a few feet.

It is only when one begins to specialize on subjects such as architecture, portraiture, high-speed work, and so on that the necessity for something better than the simple meniscus lens becomes apparent.

The great thing to remember is that the lens is the most important part of a photographer's outfit, and, other things being equal, it is better to spend as much as you can afford on the lens than on the various refinements with which some of the more expensive cameras are littered. There is very little to choose between equivalent types of lens by well-known makers. They are all good.

The length of exposure necessary with a given photographic plate or film is proportional to the brightness of the image formed by the lens. This is determined by the area of the lens and the distance behind it at which the image is formed. The ratio diameter of lens aperture/focal length of lens is called the f/ratio, and the smaller this ratio the quicker the lens. Thus, f8 means that the aperture is 1/8th of the focal length of the lens.

The lenses used in the cheapest types of camera have usually a working aperture of between f8 and f16, and a subject which requires 2 seconds' exposure when photographed with such a lens would require 1/10th second with a modern high-speed f2 lens. These big aperture lenses are therefore invaluable under poor lighting conditions. Unfortunately, as with most desirable attributes of lenses, high working speed is only obtained by making some sacrifice in other directions, and an f2 lens usually has a narrower field of view and inferior definition to one of smaller aperture (larger f number). It is also necessary to focus very critically, since the distance between the nearest and farthest objects that will appear sharp on the negatives is very small.

When high working speed is not required this 'depth of focus', as it is called, can be increased by using a smaller stop, and most lenses are fitted with an iris diaphragm which enables the effective aperture to be varied at will. The f value of the lens at various settings of the diaphragm is usually scaled on the lens mount, the usual series being f2, f2·7, f4, f5·6, f8, f11, f16, f22, and f32, and it is useful to remember that under the same lighting conditions the exposure required with each stop in this series is double that of the preceding one.

CHAPTER III

CHOOSING A CAMERA

THE word 'camera' covers a multitude of instruments varying in weight from an ounce or so to several tons, and in price from a couple of shillings to thousands of pounds. If we rule out instruments built for special purposes and toys making few pretensions to serious consideration, there still remains a bewildering variety of excellent models from which to make a choice. It is possible to take good photographs with cameras costing 5*s.* and bad ones with elaborate instruments costing £50, and perhaps the simplest way of approaching this problem is to remember that essentially a camera is a light-tight box with a lens at one end and a sensitive plate or film at the other, and that the extent and manner in which this simple design requires to be elaborated will depend on the type of photography for which it is intended.

Generally speaking, a roll-film box camera is probably the best type with which to get acquainted with the practical side of photography. It is simple in construction, easily operated, and cheap. The absence of the various adjustments which enable the more expensive types to handle a wider range of subjects is not a serious drawback to the beginner, and if his ambitions do not extend beyond making a collection of snapshot records of holidays, a $3\frac{1}{4} \times 2\frac{1}{4}$ in. model with a single achromatic lens of maximum aperture f16 will do all that he requires. With such cameras all objects over 10 feet from the camera are in focus, whilst for close-ups supplementary lenses (portrait attachments) will bring subjects 3 to 6 feet from the camera into focus. Excellent work can be done with such cameras, and expert photographers often admit that they prefer this type for recording their own lighter moments, whilst their simplicity is often invaluable.

Thus Captain Finch, the Everest climber, who has an unrivalled collection of mountaineering photographs, invariably uses the simplest form of roll film $3\frac{1}{4} \times 2\frac{1}{4}$ in. Kodak when climbing. Of 1,500 photographs made at 1/50th of a second and at one aperture, only twelve were failures. Although he intended these snapshots to be simple records

of his climbs, many of his results were of considerable technical interest, for by studying them he discovered new ways up mountains, planning his climbs during leisurely inspections of his prints. In one case the photographs showed a 'chimney' in an apparently unclimbable rock. A study of another series showed him that avalanches fell from different places at certain definite times, and he was able to draw up a time-table which enabled him to dodge them.

But the photographer whose ambitions extend beyond obtaining reasonably sharp snapshots of subjects in good light will require a more elaborate instrument than the box-form fixed-focus camera. Unfortunately there is no such thing as a perfectly satisfactory universal camera, for as the applications of photography extend more widely into the domains of science, art, and amusement, the instrument best fitted for each type of work becomes more highly specialized and hence less useful for other purposes than that for which it was designed. Accordingly, it is impossible in a generalized account of photography to give more than superficial guidance to the type of camera which is best suited to individual needs; and where there is any intention of specializing in a particular branch, the only sound course is to study a text-book on the subject.

Broadly speaking, however, general purpose cameras can be divided into four main types: the stand camera, the folding hand camera, the reflex, and the miniature camera.

The stand camera, as its name implies, is used in conjunction with a tripod. Weight is not therefore sacrificed to convenience, and this type is mainly used by professional photographers and printing firms to whom rigidity is a first consideration. A wide range of lenses can be used with these instruments, and they usually possess the following features:

Bellows. The front of the camera carrying the lens and the back carrying the plate or film are connected by extensible bellows (Fig. 7). These permit the distance between the lens and the emulsion to be altered to obtain critically sharp focus on a ground-glass screen, which is placed for the purpose in the position to be occupied later by the photographic plate. The corrugations in the bellows, which are blackened on the inside, help to trap scattered rays of light.

Swing Backs. The back of the camera carrying the plate holder can be swung about a pivot, enabling the plate to

be kept in a vertical position when the camera is tilted upwards in order to include the whole of a tall object in the photograph. In this way, the vertical lines of tall building remain parallel in the reproduction.

Rising Front. The front panel carrying the lens can be raised to get the top of a building on to the plate or to avoid the inclusion of an excessive amount of foreground. Tilting the camera for this purpose would result in an unnatural perspective in the picture—the buildings appearing to be falling backwards. This is because the upright

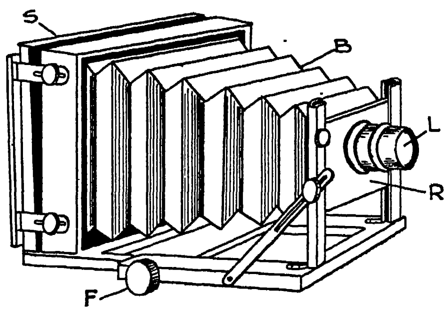


FIG. 7. L, lens; R, rising front; S, swing-back carrying plate-holder; F, focussing screw; B, bellows.

lines run together more rapidly than appears natural. It is, however, interesting to note that, if such an apparently distorted picture is held above the head and viewed by bending the head backwards, the unnatural appearance very largely vanishes.

The unnaturalness apparently lies in our normal method of viewing such pictures at eye level rather than in the photograph itself!

Stand cameras are usually fitted with a simple type of shutter, permitting time exposures (in which the shutter is opened by pressure on the release and is closed again by a second similar pressure), and bulb exposures (in which the shutter remains open only whilst the release is depressed). It is not usual to fit an automatic shutter giving a range of very short exposures, since these are not required in studio work.

Folding Hand Cameras. Although the simple box form is quite the best sort of camera with which to commence,

it has obvious limitations, and the folding hand camera is designed for a wider range of serious work.

A typical folding hand camera has bellows which enable the camera to be folded up into a compact form (Fig. 8). When opened the front locks with the lens at infinity—i.e. at a position in which all objects beyond 15–30 feet are in focus.

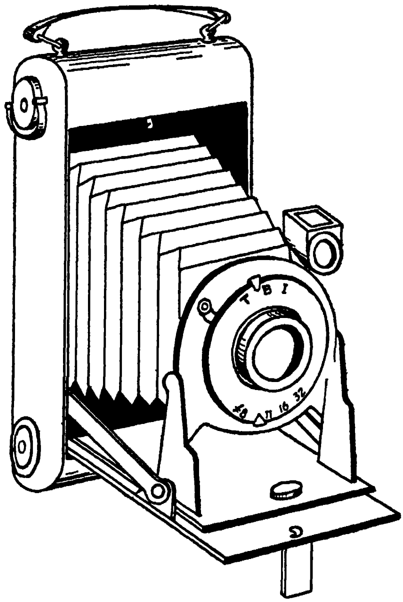


FIG. 8

Further focussing is provided for by rack and pinion or lever, which moves the lens panel backwards and forwards over the base plate, which is engraved with a scale of distances.

In the roll-film models it is usually impossible to focus directly on the ground-glass screen as with stand cameras, and view-finders, in which can be seen a miniature picture of the field of view covered by the lens, are therefore fitted.

A shutter giving a choice of exposure times in fractions of a second, and an iris diaphragm to control the amount of light passing through the lens, are the only other essential features of such cameras.

In buying a hand camera, it is well to bear in mind that

except for special purposes it is nowadays unnecessary to use a size of film or plate larger than $3\frac{1}{4} \times 2\frac{1}{4}$ in. Modern emulsions are so nearly grainless and of such beautiful gradation that there is no noticeable loss of quality in enlarging from this size up to 20×16 in.

The best all-purpose lens is an anastigmat by any well-known maker—there is little to choose between them.

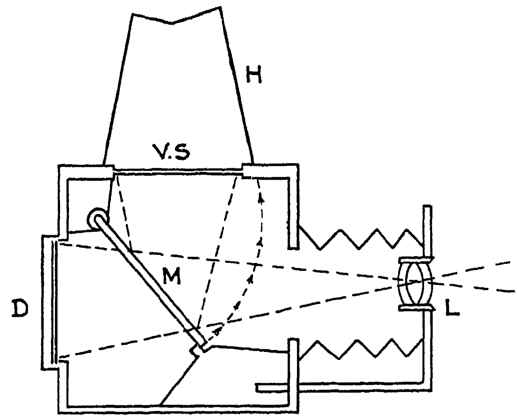


FIG. 9. TYPICAL REFLEX CAMERA

Light entering the lens L is reflected by the mirror M to the viewing screen VS within the collapsible hood H. When the exposure lever is pressed the mirror swings up to prevent light from entering the camera via VS, and shutter then opens.

Ninety per cent. of the ordinary run of photographs will not require an aperture greater than f4·5, but if one can afford it and is interested in high-speed work or colour photography, lenses giving excellent definition at f2 are available.

Landscape and portrait workers find a somewhat long focal length an advantage, while architectural photography requires a considerable choice of lenses.

Except for such specialized work, a lens whose focal length is equal to the diagonal of the plate is probably the best compromise covering the widest range of subject. This would mean a $4\frac{1}{2}$-inch lens for a $3\frac{1}{4} \times 2\frac{1}{4}$ in. camera.

The Reflex. Fifty per cent. of the photographers who exhibit at exhibitions own a reflex camera (Fig. 9). In this type the image cast by the lens is reflected on to a focussing screen

in the top of the camera by a surface silvered mirror situated at 45° to the entering rays. When the exposure is made, the first movement of the release frees the mirror, which swings up to cover the focussing screen. The exposure follows immediately, the shutter being a roller blind in which there is a horizontal slit moving rapidly in front of the plate. The width of the slit in such focal plane shutters can be adjusted, and as the speed with which the slit travels across the plate can also be altered by altering the tension of the actuating spring, exposures as short as 1/1000th of a second are possible with such shutters.

The reflex allows the photographer to arrange the composition of his picture satisfactorily, and yet be able to record it at critical focus at the psychological moment, although, owing to the necessity for getting the mirror out of the way before exposure commences, there is an inevitable lag of about 1/10th second between the actuation of the release and the actual exposure for which he may need to allow.

In order that the image on the ground-glass focussing screen may be clearly seen it is surrounded by a collapsible hood, and the convenience of this method of focussing is the main advantage of this type of camera.

The situation of the focussing screen at the top of the camera necessitates its use at a rather low view-point, and when used in street scenes it is not uncommon to find that people are present on the negative who walked into the field of view after actuation, and whose approach was not realized by the photographer with his eyes buried inside the hood.

For these and other reasons the reflex is not now as popular for high-speed work as was once the case.

The press photographer, for example, has found that it is not very convenient in the crowd attracted by his subject, and its bulk is also a drawback. A camera that is not so obviously a camera and can be hidden in the pocket enables him to get views that he would otherwise find it difficult to take. Since the speed with which a camera can be brought into action is the first consideration with the press photographer, he usually uses a camera with a focal plane shutter of the type just described, but of fixed extension with a lens in scaled focussing mount.

The press camera has a direct vision view-finder, which allows the photographer to use the camera at eye level, when any approaching figure likely to encroach on his view can

easily be seen 'out of the corner of his eye'. Although such cameras are admirable for 'news' work, focussing by scale demands accurate judgement of distances, and the construction of the camera does not permit a swing back (essential for architectural work), or the use of really short focus or wide-angle lenses.

An ingenious method of overcoming the 'focussing by scale' difficulty is to couple a direct vision range-finder with the focussing screw. The usual type of range-finder used for this purpose consists of two supplementary lenses a few

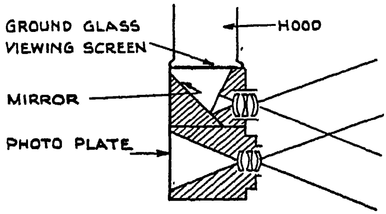


FIG. 10. TWIN LENS CAMERA

inches apart and therefore casting images from different view-points. One of these lenses is used as a direct vision view-finder, whilst the image cast from the second is reflected by prisms into the field of view. Turning the focussing screw of the lens also turns the first reflecting prism, and when the two images coalesce the object viewed is in focus.

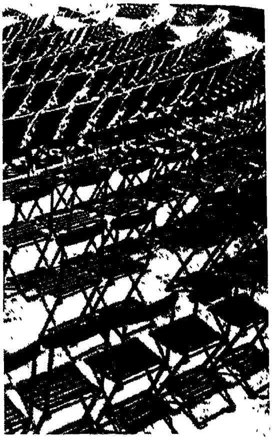
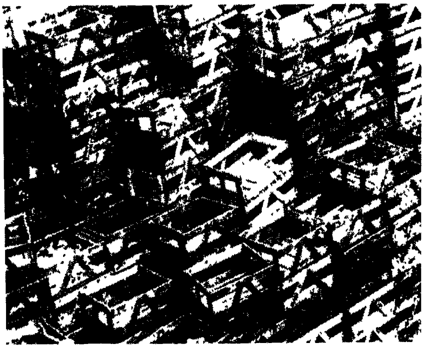
Range-finders are, however, an expensive addition to the camera, and the time lag in the normal reflex described above can be avoided by using a twin-lens camera. One of the lenses is above the other, and the image which it casts is reflected by a right-angled mirror on to a horizontal focussing screen as in the normal reflex. Since this lens is only used for focussing, it need not possess the expensive feature of the camera lens—merely the same focal length, and in effect such cameras consist of a focussing-type box-form camera with a focussing box built on top. A disadvantage of many twin-lens cameras is that for near views the view seen on the focussing screen does not correspond with that recorded on the plate (Fig. 10).

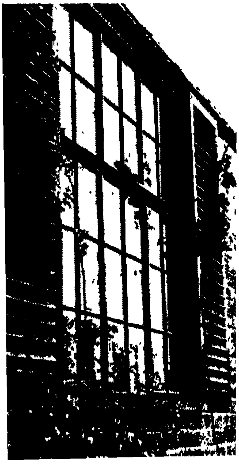
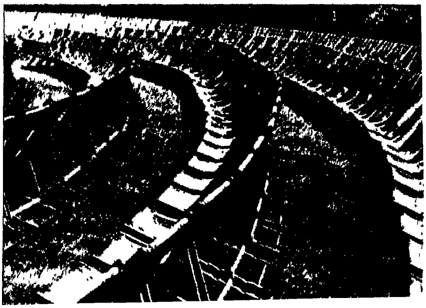
Miniature Cameras. The early types of photographic emulsion were very granular, and only a moderate degree

The Lord Chief Justice and the late Mr. Justice Avory at the Law Courts

Courtesy of Dr. Erich Salomon

Mr. Ramsay MacDonald and Mr. Stanley Baldwin photographed by Dr. Salomon

of enlargement was possible before the grain became objectionable.

With the growth in popularity of the kinema came intensive research into this problem, for the kine-film is magnified some hundred times in projection, and granularity unnoticeable in ordinary degrees of enlargement is then unpleasantly obvious. The success which has attended

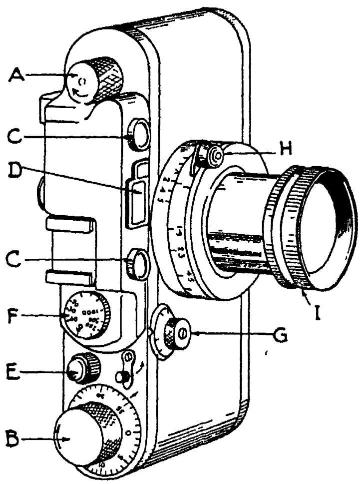


FIG. 11. TYPICAL MINIATURE CAMERA

A, rewinds film; B, winds film and sets shutter; CC, range finder; D, view finder; E, shutter release; F, sets exposures between $\frac{1}{20}$ and $\frac{1}{1000}$ second; G, sets exposures between $\frac{1}{20}$ and 1 second; H, focussing knob; I, lens, withdraws into body of camera when not in use.

these researches is having a marked influence on modern camera design, whose main tendency is towards reduction in size coupled with ease of manipulation and compactness of design.

When first introduced, the miniature camera was regarded as little more than a toy, but this type is rapidly increasing in popularity with the professional photographer. Perhaps the most interesting designs are those using standard 35 mm. kine-film as negative material, and one firm which produced six such cameras in 1924 marketed 140,000 nine years later.

They possess beautiful precision movements, are of excellent workmanship, and give negatives measuring $1 \times 1\frac{1}{2}$ in. approximately. Thanks to a better understanding of the conditions which lead to fine-grain results, these tiny negatives are now a practical proposition. When a modern, fine-grain emulsion is properly processed, using a suitable developer, grain is not seen in whole-plate enlargements, whilst pictures 5×4 feet pass muster when viewed at the distance which would be normal for such sizes.

The handiness of the instrument permits its use on occasions when the bulk of the ordinary camera would be a disadvantage. This is having a definite influence on the angle from which many photographs are taken. Pictures taken from 'worm's eye' and 'bird's eye' and other unconventional view-points are becoming increasingly familiar.

A manufacturing process can be photographed from over the shoulder of the operator, and the number of exposures which can be made in rapid succession makes natural pictures of unrehearsed incidents much easier (and incidentally cheaper) to obtain.

In poor light the miniature camera shows to great advantage because a very large-aperture lens can be used without sacrificing depth of focus to the extent obtaining with bigger cameras, and successful snapshots of theatrical stage performances, scenes on the Underground-railway platforms, &c., are obtainable with these versatile instruments. Many people, including some of the most famous press photographers, believe the miniature camera to be the photographic recording apparatus of the future.

APPENDIX

A statistical survey by the weekly periodical *The Amateur Photographer* as to the cameras favoured by prominent photographers specializing in pictorial work shows the following distribution of types and sizes of camera:

	Per cent.	*Per cent.*
1. Reflex		
(*a*) Using reflex exclusively	59	..
(*b*) Using reflex alternatively with $3\frac{1}{2} \times 2\frac{1}{2}$ in. or $2\frac{1}{4} \times 2\frac{1}{4}$ in. folding or hand camera . .	$7\frac{1}{2}$	..
(*c*) Using reflex alternatively with half-plate stand or field camera	$2\frac{1}{2}$	69

	Per cent.
2. Folding and hand cameras	18
3. Stand and field cameras	9
4. Miniature cameras (24×36 mm.)	2½
5. Stereo camera (single exposures)	1½

(In 2, 3, 4, and 5, 21 per cent. of the owners also used a reflex alternatively.)

Sizes of reflex cameras

	Per cent.
1. Quarter plate	64
2. 3½×2½	27
3. 5×4	3½
4. 9×12 cm.	2
5. Not specified	3½

Sizes of other cameras

	Per cent.
1. 3½×2½ and 3¼×2¼	53
2. Quarter plate	19
3. Half plate	12½
4. Miniature	6¼
5. 2¼×2¼	6¼
6. 5×4	3

It is safe to state that the popularity of the miniature camera has increased very considerably since this survey was made.

CHAPTER IV

LENSES AND CAMERAS FOR SPECIAL PURPOSES

It has been explained that even the most expensive lenses have limitations, and the enhancement of any particular characteristic required for special types of photography usually results in the lens being less useful for purposes other than those for which it was designed.

Sooner or later, therefore, any one who intends to do more than dabble in photography will begin to acquire a collection of lenses, each of which does one particular thing particularly well.

The portrait photographer requires portrait lenses of no value in architectural photography; interior photography demands wide-angle lenses useless for portraiture; the press photographer has a high-speed lens whose definition will not satisfy the process engraver; and the colour worker requires completely colour-corrected lenses, which show no advantage to the monochrome worker over lenses half the price.

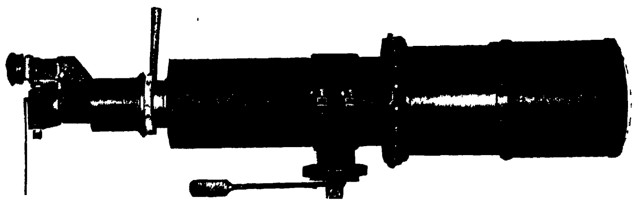
The next requirement of all workers is a choice of different focal lengths, and the second lens that the serious amateur photographer will buy is one of longer focal length than that of the general-purpose type supplied with the better quality hand cameras.

Most photographers are disappointed with their first photograph of a distant range of mountains. An ordinary general-purposes lens is apt to render them as though they were a row of molehills. This drawback can be overcome by using a very long focus lens—the so-called telephoto. If, for example, for a lens with a focal length of 6 inches,which renders a distant object so small that it can be hidden by putting a threepenny-bit on the negative, we substitute a 12-in. lens, the image will cover four times the area, and will not therefore be completely hidden by half a crown. With such long-focus lenses it is necessary to sacrifice some of the field of view, to focus more accurately, and to be content with a slower working speed. Moreover, the magnification of the image obtained by a very long focus lens is accompanied by a distortion of the perspective. You may have

A photographer's equipment in 1874

And to-day. *Courtesy of Wallace Heaton, Lt*

The tiniest camera in the worl
made by Messrs. Kodak Ltd. fo
Queen Mary's Doll's House. It i
only three-quarters of an inc
in height



noticed in telephotographs of Test-match players at the wicket that nearly end-on views of the pitch make it appear to be only a few feet long. A very short focus lens will give the opposite impression, particularly when the subject is close to the camera. For ordinary work the most useful focal length is one which is a little longer than the diagonal of the film or plate, and for a $3\frac{1}{2} \times 2\frac{1}{2}$ in. camera a lens of focal length of $4\frac{1}{2}$ inches is about right. Portrait photographers prefer a somewhat longer focal length (8–12 in.) since, in addition to giving improved modelling, it is easier to isolate the subject from unwanted background details.

Telephoto lenses may have focal lengths as long as 40 inches, and their value when photographing distant scenery, sports meetings, details of architecture in inaccessible positions, &c., is obvious. In natural history photography the telephoto is invaluable, and the hunting of big game has been giving place in recent years to the stalking of wild animals with a camera. Besides being a more humane and sensible sport, wonderful records have been brought back which from many points of view are of considerably greater interest than the collections of skins and horns which was all the hunter had to show. You cannot gain much information as to the life and habits of a wild creature if you have killed it, whereas photographs obtained under equally thrilling conditions are very often interesting zoologically, more particularly as many herds of big game are dwindling so rapidly that the total extinction of some species is only a few years away.

While lenses designed for special purposes still remain recognizable as such, many of the specialized cameras produced within the last few years bear only the remotest resemblance to the parent type. Space precludes description of more than a few typical examples of such instruments.

Aerial Photography. The earliest aerial photographs were obtained by pointing an ordinary camera over the side of the plane, and it is quite possible for the amateur to make attractive souvenirs of his flights in this way. Even though the machine may be flying at 100 m.p.h., snapshots with the cheapest form of box camera will give quite sharp perspective views of the landscape, providing that this is 3,000 to 4,000 feet away, the weather is brilliantly clear with no mist or haze, and that the camera is held steadily in a position where it is well protected by the wind-screen.

It is as well to remember that if the camera is actually held *over* the side of the plane it will be impossible to keep it steady, even if the force of the wind does not wrench it out of your grip, and the best method is to hold the camera firmly against the forehead, sighting by looking along one edge and then, keeping the arms firmly pressed against the body so that the minimum of vibration is transmitted to the camera, gently squeeze the release.

Aerial photography became firmly established as a result of the War; specialized cameras for this type of work were soon developed, and nearly seven million aerial photographs were issued to the armies during 1918.

In peace time the chief value of such photography is the rapid production of maps, using cameras mounted vertically over a well in the floor of the aeroplane. A typical camera is electrically operated by remote control from the cockpit, and will expose, inform the pilot of the fact by flashing a light, wind the film, and reset the shutter at accurate intervals until it announces by another signal that the magazine is empty. The dials of instruments recording altitude, time, sequence number, and degree of tilt are all photographed along the edge of the film at each exposure, simplifying the identification and interpretation of each view. The only attention required during a flight is to reload by changing the magazine after 200 exposures. The exposures are so timed that each picture overlaps its neighbour as the pilot flies his machine as steadily as possible backwards and forwards over the area to be mapped, being given his bearings by directional wireless from the ground. The time is probably not far distant when a human pilot will be unnecessary, the camera, fitted with its own wings, engine and propellor being completely controlled in its flight by directional radio from the base. The prints are assembled into a mosaic from which a map of the country over which the plane has flown can be constructed. As yet such maps are not so informative as those reproduced by the usual methods of surveying, more particularly since it is an intricate matter to calculate the contours as opposed to the general layout of the ground from such photographs. On the other hand, this method enables an enormous amount of ground to be covered and mapped in a very short time, whilst for inaccessible or difficult country such as the jungles and swamps of Africa, aerial mapping is invaluable. Thus the international

boundary line between Rhodesia and the Belgian Congo was agreed on the basis of aerial photographs, no white man ever having traversed this border on foot.

The method so far described depends upon photographing the ground over which the plane flies, but it is also possible to convert oblique (perspective) views of the country into maps by superposing on such photographs a grid representing a perspective view of imaginary squares, and then redrawing the grid in plan form, filling in the detail in relation to the size of the square which contains it (see Plate 9). All points which lie on the straight lines constituting the grid will be on straight lines on the ground.

Photo-sculpture. An interesting extension of this method of photographic surveying enables sculptures in relief to be made from photographs. This process depends upon the observation that if a regular pattern, e.g. a helicle spiral, is projected on to a flat surface, the image produced is undistorted, but that when the flat screen is replaced by an irregular solid object, the image of the regular pattern will be distorted by reason of the contours of this object. The distorted shape of the spiral as it falls on the subject is recorded on a photographic plate, and the guide plate so prepared is placed on the bed of a microscope coupled up with an electrically driven drill. The microscope is made by hand to follow the lines of the distorted spiral on the guide plate, and in doing so guides the drill so that it automatically cuts a furrow in the material of the right depth. Any one who has grasped the relationship between a relief map and a contour map will readily understand the principle involved.

Stereoscopic Cameras. The machine just described, which produces what is, in effect, a photograph in relief, costs hundreds of pounds, but an illusion of relief can be obtained by so-called stereoscopic photography for an outlay of a few shillings. Objects have an appearance of solidity because we look at them with two eyes, each of which has a slightly different view-point. Each eye sees a little farther round one side of an object than the other, though we are normally only conscious of this fact when, keeping the head stationary, we examine a not too distant scene first with one eye and then with the other. The two different images are added together by the brain to form one impression, and the sensation of solidity is produced.

But the eye is really a specialized form of camera, complete with a lens whose working aperture is adjustable by the iris diaphragm from f1·5 to f8 at one end, and the retina, or human equivalent of the photographic plate, at the other. It even has a shutter—the eyelid!

If for the two eyes we substitute the mechanical equivalent in the form of two cameras side by side, whose lenses are about 2 inches apart, one of these will photograph the view as seen by the left eye and the other as seen by the right. If the two photographs obtained in this way are viewed simultaneously in an instrument which permits the left eye to see only the left camera picture and the right eye the other, then the two pictures fuse together in the brain just as the normal visual images do, to give a so-called stereoscopic picture which is apparently three-dimensional. An ingenious way of causing the two images to fuse which does not necessitate an elaborate viewing instrument is to colour one of the images orange and the other green, and print them one on top of the other. If now this composite picture (usually called an anaglyph) is viewed through spectacles, one eyepiece of which is covered with orange glass and the other with blue-green, the image is seen in relief. The function of the coloured filters will be clearer after a study of Chapter IX, but, briefly, when an orange image on white paper is viewed through an orange glass it is impossible to detect where the coloured image leaves off and the white paper begins, the whole surface appearing a uniform orange colour. On the other hand, the blue-green image looks black through the orange glass. The eye covered by the orange filter therefore only sees the green image. For the same reason the eye covered with the blue-green filter sees the orange image as black but is unable to distinguish the outlines of the blue-green image from the blue-green appearance of the paper. The necessary condition that each eye shall only see one of the images is thus fulfilled.

The two photographs required to form a stereoscopic image are usually taken simultaneously in a specially designed twin-lens camera, but this is not essential for still-life work, since if, after making one exposure with an ordinary camera, the latter is moved to a fresh position an inch or so to the left or right, a second picture corresponding to the second eye view can then be taken. Although such

stereoscopic pictures are not nowadays so popular as a source of entertainment as was once the case, they are of considerable value in industry, surgery, and in scientific research. Thus manufacturers of complicated machinery which is to be erected abroad frequently supply stereoscopic photographs showing the appearance of the plant at various stages of erection.

When these photographs are viewed in a stereoscope by the foreign client and his mechanics, they obtain a clearer idea of the way the various parts are to be fitted together.

Stereoscopic X-ray photographs will enable the surgeon to locate the position in a patient's body of foreign substances or malignant growths. Stereoscopic aerial photographs are frequently much more easily interpreted than the ordinary two-dimensional plan-view. Owing to the distance of the landscape from the aeroplane, however, such stereoscopic photographs are not usually made with a twin-lens camera; since this would give a degree of relief of the order of that seen by the eyes, and in the case of very distant objects the impression of solidity is then very slight. To increase the effect and give such distant objects a satisfactory appearance of solidity, it is only necessary to increase the distance between the two points from which the photographs are taken. In aerial surveying this can be done by taking one photograph a second or so after the other, when the view-point of each is separated by the distance the aeroplane has travelled in that time.

When such photographs are examined in a stereoscope the various planes in the picture are separated out in a much more obvious and useful manner than is the case when the same scene is examined visually from a similar distance.

The farther away an object is the less 'stereoscopic' it appears, and in order, for example, to see the moon as a solid ball rather than a flat disk it would be necessary that our eyes should be about 20,000 miles apart, since only with this separation could we see two sufficiently different views of its surface. Nevertheless, stereoscopic photographs of the moon have been made by taking advantage of the fact that, although the moon always turns the same face towards the earth, there is a slight periodic swinging movement about its axis. When it has swung to the left as far as it will go we see slightly more of the right-hand surface. Then as it swings to the right it exposes a narrow strip of the left-

hand edge which was previously hidden. If we photograph these two slightly different views, each looking a little farther round one side than the other, they form a stereoscopic pair. The period of the swinging movement is very slow, and it is necessary to wait four years between taking the two pictures which will represent the left- and right-eye view of a giant about 60,000 miles high!

Astronomical Cameras. The photographic plate has been called the retina of the scientist, and the astronomer would be the first to acknowledge the justice of this description, since modern astronomical observation is carried out almost entirely by photography. One of the most valuable characteristics of the photographic plate in this connexion is its ability to store up the effect of very faint light over long periods of time. This the eye is unable to do, for if we stare for a long time at a faint object we do not see it any better but rather worse than at first glance. Thus, there is an area in the constellation of Orion in which the unaided eye can detect about 100 stars: a photograph of the same area taken on an ordinary Kodak and exposed for one hour showed about 6,500 stars, whilst with an astronomical camera a small portion of this same field is recorded as a white blaze of stars. Whereas the naked eye can detect about 10,500 stars, the photographic plate in conjunction with the Mount Wilson telescope has recorded approximately 288,000,000,000!

To counteract the earth's rotation and consequent apparent shift of the stars during the exposures, which may be upwards of four hours, the telescopic camera is kept moving by clockwork round an axle pointing to the hub of the sky. In this way it is possible to expose on the same region of the sky for hours at a time without the smallest shift of the image.

In photographing the most distant stars the astronomer is recording lights of about the same intensity as would be obtained from a candle several million miles away, and it is not possible to construct lenses large enough for this purpose. However, a concave mirror acts in the same way as a lens in that it bends the light rays falling on to it, bringing them to a focus at a point in front of it; and although such an arrangement would not be suitable for ordinary photography owing to the impracticability of preventing stray light from fogging the plate, it is suitable for use at night

and in the form of a telescope. Whereas the practical limit to the diameter of a lens is about 40 inches, a concave mirror with an aperture of 200 inches is being erected at Mount Wilson in California, and this observatory has been using 100-inch reflector for several years at the bottom of its 100-feet tower telescope.

It is a staggering thought that with the aid of such instruments the distance and composition of stars whose light, travelling at 186,000 miles a second, takes millions of years to reach the earth, has been determined.

In calculating these distances use is made of the knowledge that if the length of one side and the value of two angles of a triangle are known, its height can be calculated. If, therefore, we can measure a base line and the angles made by lines joining each end to the star, its distance can be found. But no terrestrial base line is long enough for accurate measurement of these angles to be possible, and use is made of the knowledge that the solar system is moving towards Vega at 12 miles per second; consequently photographs taken twenty years ago of a star and of the same star now gives us an enormous base line which is sufficiently long for the purpose.

The composition of the stars is determined by examining photographs of their spectrum. We have already seen that a prism is capable of analysing white light into its components, and spectrum analysis depends upon the fact that the nature of the light which is radiated by a luminous body depends upon the latter's constitution. The characteristic colours of the various gaseous discharge tubes used in floodlighting, the yellow light obtained by putting common salt in a hot flame, and so on, are due to the radiation of groups of rays of wave length peculiar to each substance. The light from the stars is a composite mixture of many such characteristic groups, and by dispersing the light into a spectrum we are able, from the spectrum photograph, to identify the elements.

The Intra-gastric Camera. We need not leave the earth to find instances in which the camera provides the only possible means of studying a phenomenon, and a striking contrast to the giant astronomical camera is provided by a tiny camera which, when swallowed, will take stereoscopic photographs of the inside of a patient's stomach!

The camera, which is less than ½ inch wide, consists of a

cylinder divided into two parts by a chamber containing a tungsten filament which, when arc discharged, provides a brilliant flash of light lasting 1/10,000th of a second. Sixteen pictures of the inside of a stomach are obtained by the light of this flash through pin-holes spaced round the circumference of the tube.

The ability to make photographs by such extremely short exposures to high intensity light has been applied in many directions, and by using electric arc discharges as a source of illumination, subjects have been photographed by exposures as short as two-millionths of a second.

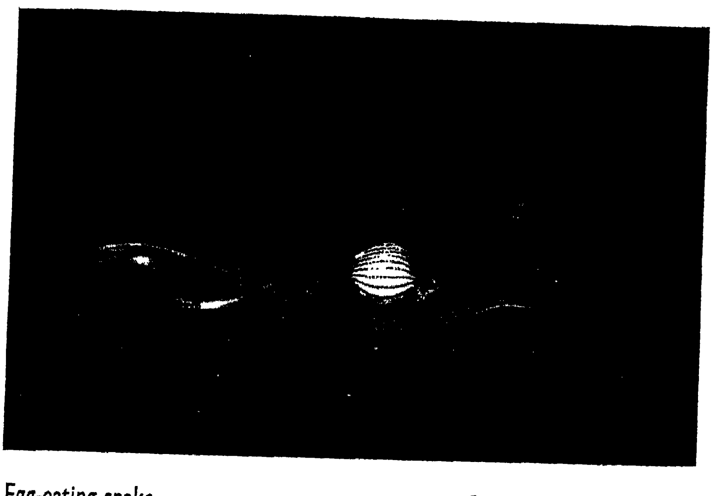
When photographing such subjects as bullets in flight it is necessary to ensure that the spark occurs at the right instant of time, and many ingenious methods are used to ensure that this is the case. As early as 1893 C. V. Boys was using the bullets themselves to fire the trigger arrangement by passing between the spark gap and thus ensuring discharge.

The silhouette photographs show the shadow of the compression wave produced by the bullet and visible in the plate because of the local difference in the density, and hence refractive index, of the air. The shape of these waves enables the velocity of the bullets to be calculated (Plate 37). In addition to photographing the bullet, the camera has replaced it in training Air Force machine gunners. When the trigger of the gun is pressed a photograph of the target at which the photograph gun is aimed is taken and the accuracy of the gunner's aim is thus recorded (Plate 12). It is therefore unnecessary in manœuvres that real bullets be fired, and when this method is applied to gunnery the heavy cost of shells is saved.

Another unusual camera which is expected to effect considerable economies over previous practice is the photographic type-setter. This photographs individual letters, of which there may be thirty different styles carried on a transparent ribbon 30 feet long. Each letter can then be reproduced in as many as ninety different sizes, and the resulting negative used to make printing blocks. Thus one ribbon will serve the printer in place of 2,700 different founts of type!

Fascination of snow

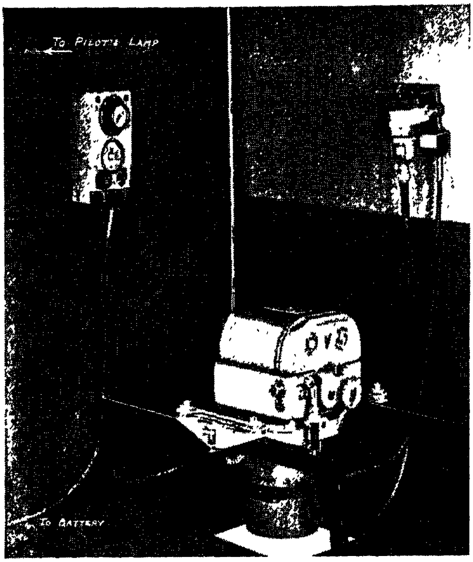
Asahi Copyright



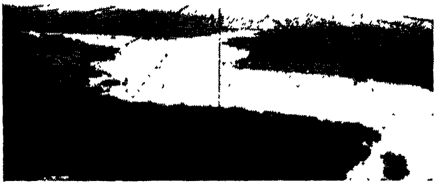
Egg-eating snake

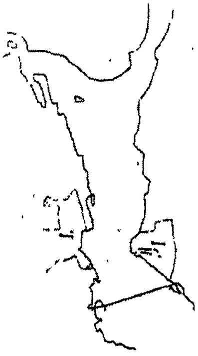
Courtesy of F. W. Bond, F.R.P.S.

PLATE 9



Typical installation in aircraft of the Eagle III camera with electric drive and control





An oblique photograph with mapping grid superimposed. Below is shown a plan drawn

CHAPTER V

THE PHOTOGRAPHIC EMULSION

UNDER the action of light, compounds of silver are decomposed with the liberation of metallic silver. If the light is sufficiently strong or its action sufficiently prolonged, very thin layers of silver salts can be completely decomposed, while in the case of silver chloride or bromide, exposure of the salt to sunlight for a few minutes is sufficient to produce a visible darkening owing to the liberation over the surface of finely divided silver.

The black deposit looks very unlike shining massive silver, just as black carbon looks unlike a glittering diamond or a heap of stones looks unlike a cathedral, and the reason is the same in each case. The ultimate particles are arranged in no sort of order, and properties such as 'lustre' which are dependent upon ordered arrangement cannot therefore exist.

Practically every known substance is affected in some way or other by light, and the unique position of insoluble silver salts in photography is due not so much to the fact that the change which exposure to light produces is visible and permanent, as that the effect of exposures which are so short that no visible alteration is produced can nevertheless be made manifest by after-treatment—the process called development.

The method of developing this invisible image, discovered independently by Daguerre and Fox Talbot, is similar in principle to that by which a detective develops invisible finger-prints left on a smooth surface. The detective dusts the surface with fine powder and then blows the surplus away, when the grease lines retain sufficient powder to be easily seen. Daguerre amalgamated the latent image, as it is called, by holding his exposed plates over mercury vapour, whilst Fox Talbot silver plated it by immersing his exposed sheets of sensitive paper in solutions which readily deposited silver. In each case the metal added itself to the invisibly small image produced by the light action until it had grown large enough to be seen.

Fox Talbot's method of development is no longer used in general practice because, once the existence of the latent image had been demonstrated, more convenient and reliable

means of development were devised; while Daguerre's system required that the mercury vapour had free access to the latent image, and this is not possible with modern material in which the silver compounds are embedded in gelatine.

Nowadays advantage is taken of the knowledge that, of the many substances capable of removing the bromine from silver bromide and leaving metallic silver, there are some which just fail to do this unless the silver bromide has first been exposed to light. These substances are therefore able to discriminate between exposed and unexposed silver bromide in that they reduce the former to silver and leave the latter untouched. This special form of light sensitivity whereby a 'latent image' is formed on very short exposure which can afterwards be developed up to a visible image appears to be confined to the insoluble compounds of silver and chlorine, bromide and iodine—the so-called halogen elements—when these compounds are precipitated in the presence of gelatine.[1]

Although originally employed as a convenient transparent vehicle for holding the insoluble silver salts in place during processing, gelatine was found to contribute materially to their natural light sensitivity, and its unique behaviour in this respect was one of the most important discoveries in the history of photography.

To be of any use photographically it is of course essential that the silver halide-gelatine complex be prepared in darkness, and a typical procedure would be as follows:

Twenty-five grams of potassium bromide is added to a warm solution of 25 grams of gelatine in 200 c.c. of water. When the bromide has dissolved it is removed to a dark-room where a solution of 30 grams of silver nitrate in 200 c.c. of water is slowly added with constant stirring, whereupon the light sensitive silver bromide is thrown out of solution as a creamy precipitate which, owing to the presence of the gelatine, remains suspended throughout the liquid instead of settling down to the bottom of the vessel. The reaction can be expressed

silver nitrate + potassium bromide → silver bromide (insoluble) + potassium nitrate.

At this point we will divide the emulsion of silver bromide suspended in gelatine into two parts. One portion, while

[1] Recently (Jan. 1936) it has been found possible to produce a latent image in Thallium Halides.

still warm, is flowed over a sheet of paper and chilled, whereupon it sets to a jelly. The coated paper is dried in a current of warm air and stored in a light-tight box. The vessel containing the remainder of the emulsion is placed in a pan of boiling water so that it can be kept hot for about ten minutes after its preparation. It is then flowed over glass plates, and chilled. The chilled plates are soaked for a few minutes in cold water which leaches out the soluble potassium nitrate and then the emulsion is dried down to a thin, smooth coating, when it is ready for exposure in the camera.

It will not be a very good emulsion, as modern emulsions go, any more than our pin-hole camera was a very good camera; but if we have been careful to keep all light away from it during preparation we could certainly take photographs with it that would have staggered Fox Talbot.

Let us suppose that we have dwindled to about 1/1000th of an inch in height, that we can see in the dark, and that we can move about inside the emulsion we have prepared. We should find ourselves surrounded on all sides by clear yellow crystals of silver bromide separated from each other by the gelatine in which they are embedded. Most of the crystals would be flat triangular or hexagonal plates, and in the emulsion on the paper support they would vary in size from our fist to our thumb-nail, whereas in the emulsion on the glass, which we had kept hot for some time before coating, there would be a large proportion of crystals as big as our head and relatively fewer of the small thumb-nail crystals. The average size of the crystals in the emulsion which has been cooked (or 'ripened') is larger than that in the uncooked emulsion. This is because we used more potassium bromide than was required to react completely with the silver nitrate, and silver bromide is slightly soluble in hot potassium bromide solutions. The tiny crystals are therefore able to dissolve, their silver bromide being re-deposited on the larger crystals. It is difficult to explain in a few words why the larger crystals should grow at the expense of the small ones, but Nature always tries to reduce the area of exposed surfaces wherever it has the opportunity, and since the ratio surface/volume is enormously greater with small objects than with large ones, the rearrangement as larger crystals results in a reduction of the total surface area of the silver bromide.

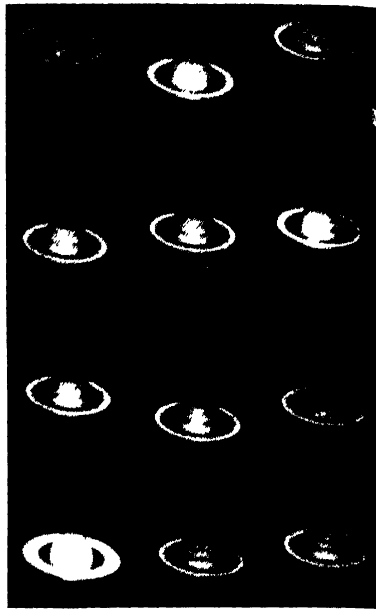
The majority of the crystals will have turned so that their flat faces are facing the surface of the emulsion before the gelatine set and fixed them permanently in position, but they are distributed throughout the gelatine in no sort of order, some being isolated as solitary individuals, whilst others are clustered together in clumps.

Let us assume that while we are still wandering about inside the glass-plate emulsion a photograph is taken on it of a church interior—the view including a stained-glass window. It is not a very suitable subject for a first attempt, though the very first photograph that Fox Talbot made was actually of a window in Lacock Abbey. For a short time the darkness around us is lit up as rays of light pass through the gelatine emulsion to the glass support beneath. If we examine the crystals after this exposure no visible alteration will be detected, and it is not until after the plate has been immersed in the developing solution that the effect which light has had is manifested. A few seconds after the developer has penetrated the gelatine small black specks will begin to appear on the surface of some of the bigger crystals. The specks grow rapidly in size, spreading over the surface, and at the end of five minutes those crystals which have been affected will have been completely converted into black, coke-like masses of silver. The number of crystals so transformed will, even in the most fully exposed portions of the emulsion, be only a fraction of the total number, the remainder being apparently unchanged by the developing process. Moreover, we shall find that, generally speaking, the largest grains were the most light sensitive, for in any given area a greater proportion of the large grains will have been converted into silver. It follows that the ripening process which resulted in the average grain size of the emulsion coated on glass being increased has made this emulsion much more light-sensitive than the unripened emulsion we coated on paper.

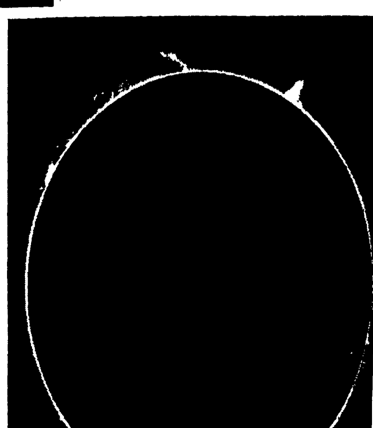
What exactly happens when light strikes the silver bromide crystal is still a mystery. All we can safely say is that scattered over the surface of the crystal there are tiny areas which are extremely sensitive to light. These areas constitute less than a millionth of the grain surface, and they form nuclei from which development commences. It is the presence of these sub-microscopic nuclei which gives the emulsion its extreme sensitivity to light, the rest of the grain

Nebula in Andromeda *Photo.: Ritchey*

Twelve exposures of the planet Saturn taken through 60-in. telescope



Spiral nebula on edge in Andromeda. Exposure 7 hours 15 minutes



merely supplying the silver necessary to build up a visible image around the fundamentally vital spots which light has somehow affected.

When development is complete the plate is transferred to the fixing solution, and as this penetrates the emulsion and surrounds the unaffected crystals they begin to dissolve, and at the end of a few minutes have disappeared, leaving only the metallic silver grains which form the photographic image.

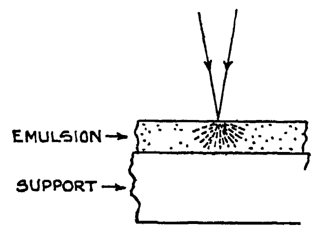


FIG. 12. SCATTER IN EMULSION (IRRADIATION)

Before we leave the emulsion let us have a careful look round —it will help us to understand some of the peculiarities we encounter in our negatives. Here is a point where a very thin shaft of bright light entered the emulsion—it may have been the image of an electric lamp filament. As the rays of light penetrated deeper and deeper below the surface they obviously became scattered by reflection from the surfaces of the grains, and by the time the light reached the glass support the grains which it had affected were spread over a larger area than the original image (Fig. 12). Moreover, the air-glass surface of the support had reflected some of the light which reached it back into the emulsion, resulting in a further spreading of the light (Fig. 13).

As a result, the original image of the filament will be recorded in the emulsion by a band of developed grains which is obviously too broad and at the same time ill defined.

Now let us go to the place where the image of the stained-glass window fell on the emulsion. Here is a point where blue light from a blue pane entered the emulsion, and the number of developed grains is very large. Next to it is an area where red rays from a red pane fell, and very few developed grains are present, the emulsion being almost clear. Although, therefore, light from the red pane arouses an appreciably more intense sensation in the eye than from the dark blue, it has been without effect on the silver bromide. The emulsion we have prepared is apparently colour blind to red light.

When we recall the enormous range of electro-magnetic

rays with properties varying continuously with wave-length, it is not surprising to find that the particular rays which affect silver bromide in the peculiar manner we have been examining are not identical in wave-length with the relatively narrow band of rays which arouses in the eye the sensation of vision.

As it happens, however, the band of chemically active rays which affect silver salts and the visual rays by which we see overlap between 4,000 Å.U. and 5,000 Å.U., and rays between those wave-lengths not only affect silver bromide but also give rise in our eyes to the sensation of violet and blue light. We shall consider this point in greater detail in Chapter IX.

Now let us return to our normal dimensions and examine the photographic plate in the light of the knowledge we have gained. As we increase in size the individual grains become too small to see, though the largest clumps are still visible, just as a wood can be seen at distances too great to distinguish the individual trees. Eventually these also merge into apparently continuous grey layers whose shapes correspond to the arrangement of patches of light of different brightness which constituted the image cast by the lens. Wherever light has fallen a black layer of silver has resulted, and the brighter the light the blacker the deposit. Although, therefore, the shapes of the patches of light is correctly rendered, the luminosities of the subject are inverted. We can correct this state of affairs by simply placing the 'negative' image in contact with the silver bromide emulsion coated on paper and exposing the latter to light through the negative. The amount of light reaching the 'bromide' paper will be determined in each area by the amount of silver in the negative above it, and as most light will get through those areas where the negative has least silver and vice versa, on developing and fixing the bromide paper the light shade on the print will be the converse of those on the negative, and therefore correspond to the light and shade of the original scene photographed.

The image is built up of grains of silver. This being the case, the apparently continuous black areas of our negative must actually be granular in nature. If we look at these areas under a magnifying glass we can confirm that this is the case, although we cannot see the individual grains themselves, but merely the clumps. The total bulk of silver

bromide present on a vest-pocket roll film is about the size of a raindrop, but it is so minutely subdivided that the emulsion coating on such a film contains somewhere about two hundred million separate particles. In some emulsions the actual grains are so small that we could easily accommodate 500,000 without overlapping on the head of a pin.

However, the practical result of this clumping together of the grains will be a limitation in the size to which we can enlarge a photograph without the granular nature of the image becoming unpleasantly obvious.

The grains scatter the light rays. We have learned that, to a certain extent, the image spreads in somewhat the same way as does an ink stroke drawn on blotting-paper. There is therefore a limit to the fineness of detail which we can render. Actually a normal commercial emulsion can just about distinguish between lines which are 1/1000th of an inch apart, and lines which in the image cast by the lens are closer together than this will be rendered in the negative as a uniform grey patch owing to the spreading of the image within the emulsion.

It follows that the smaller the grains in an emulsion and, even more important, the less these clump together, the greater the degree of magnification and rendering of fine detail which will be possible. Since, however, we saw that the bigger grains were most light-sensitive, it follows that the greater the speed of the emulsion, the larger the proportion of larger grains, the more obvious the clumping; hence the higher the working speed the more granular the result, and the worse the 'resolving power', as ability to render fine detail is called. These considerations are of considerable importance in kinematography, where images 1½ inch wide are frequently enlarged on to a screen 24 feet wide. The positive film on which kine negatives are printed has a slow, fine-grained emulsion, but this is only a partial cure, for the clumps of grains in the original negative will of course print as clumps on the positive. As a result of the demand by the kine industry for the minimum of granularity, emulsions have now been produced in which clumping of grains is reduced to a minimum. A further reduction in graininess is possible by using with such emulsions special developers whose activities are so regulated that development of the least exposed grains is well on the way before the most fully exposed clumps are completely trans-

formed into silver and then stopping development at this point. This technique will obviously result in less silver being present in the fully exposed portions than would be the case if development had been taken to completion, and these portions will appear grey rather than dense black. There will therefore be less visible difference between the shadows and highlights of the image. This technique whereby the contrast between highlights and shadow is deliberately restricted by partial development with con-

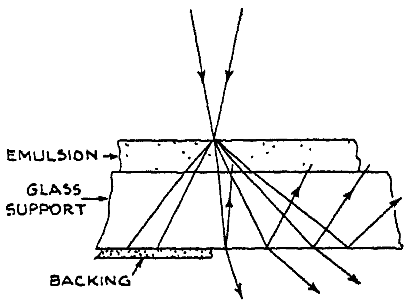


FIG. 13. HALATION IN PLATE.

sequent reduction of granularity is becoming increasingly important, and we shall return to the subject later.

Some of the light rays are reflected back into the emulsion from the air glass surface at the back of the plate (Fig. 13). This explains the halo that surrounds the image of very bright subjects such as windows, bright reflections from metal or glass surfaces, lighted lamps, &c. The thin lead strips which separate the panes of glass in the stained-glass window are not visible in our picture because the image of the panes of glass have spread by reflection from the glass surface so considerably that they have joined up. Inspection of Fig. 13 will show that the thicker the glass the wider will be this spreading, and halation (as it is called) is less troublesome on films since the relatively thin celluloid support allows the light very little room in which to spread.

Halation can be completely eliminated by giving the back of the plate or film a suitable coating which absorbs light. If, for example, the glass surface is coated with light absorbing dyestuffs, before those rays of light which have passed through the emulsion can reach the air surface at which the harmful reflections would take place, they must

Vertical photograph taken with Williamson Eagle III camera by the Houston Mt. Everest expedition over the Himalayas. It will be noticed that the height reached is 31,750 feet, a photographic altitude record. The camera was operated automatically by electric control in a temperature of −60° Centigrade. (Actual size of air view, 5 in. × 5 in.) *Courtesy of The Times*

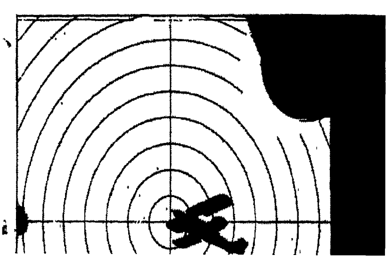
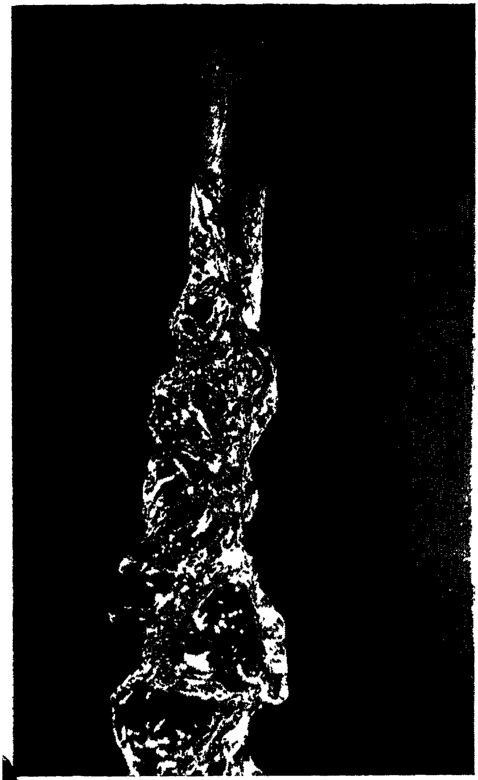


PLATE 13



Photograph of water from ordinary tap. Exposure 1/50,000th second made with a spark in air obtained by discharging a condenser which was charged to about 8,000 volts

Reproduced by courtesy of H. E. Edgerton, Massachusetts Institute of Technology, Cambridge, Mass.

enter this coating and be absorbed.[1] Having served its purpose, the backing washes away during processing. Irradiation, the internal scattering of light by reflection from the grains themselves, cannot of course be eliminated by such a backing.

Only a fraction of the grains are rendered developable by light exposure, and the number increases with exposure.

A little thought will show that if the grains of an emulsion were all equally sensitive to light there would only be two tones rendered in a photograph—white and black—since in any area all the grains would develop or none at all.

Because the emulsion is made up of grains of varying sensitivity it is possible to render intermediate tones. Thus where a weak light falls on the emulsion only the most sensitive (usually the largest) grains are rendered developable. A somewhat stronger illumination results in the most sensitive and some of the medium sensitive grains becoming developable, whilst a strong light results in big, medium, and small grains all blackening on development.

If the tones of the final picture are to correspond with those of the original subject, the various blacknesses or 'densities' produced in the negative must correspond with the various brightnesses of the subject photographed. The simplest way of finding out if this is the case in practice is to expose the photographic plate to a series of known brightnesses and measure the density which is produced by each exposure. When this is done it is found that the gain in density with increasing exposure is not uniform over a wide range of exposures, since very low brightnesses (or very short exposures) and very high brightnesses (or full exposures) do not show an equal rise in density for each equal increase in exposure, and the result when expressed graphically takes the form of an S-shaped curve whose shape varies with the type of emulsion. Yet in between the extremes there is a region of correct exposure where the density increases by the same amount for a given relative increase of exposure.

Incidentally, this S-shaped curve is characteristic of many natural phenomena, there being commonly an initial period of slow growth whilst the change in conditions is

[1] The emulsion whose preparation has been described is sensitive only to blue light. It is not therefore necessary to use a black backing—an orange coating which absorbs the blue rays being sufficient.

'getting under way', then a period where constant proportionality is maintained, and finally a slowing down as the material fails to respond adequately to the very strong stimulus supplied.

Fig. 14 shows a typical curve.[1] The brightness of the test object is plotted along AB in terms of foot candles. Thus 1 represents a brightness of one candle at one foot away, 4 represents a brightness equal to 4 candles one foot away, and so on. The blackness or 'density', produced in the

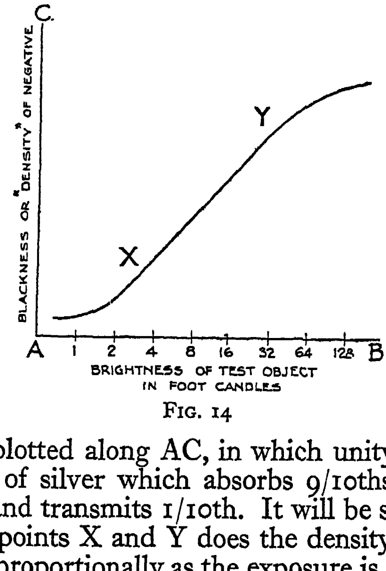


FIG. 14

negative, is plotted along AC, in which unity corresponds to a density of silver which absorbs 9/10ths of the light falling on it and transmits 1/10th. It will be seen that only between the points X and Y does the density of the negative increase proportionally as the exposure is doubled.

If we are to obtain a correct rendering of the light and shade of the original we must as far as possible keep our record on this straight line portion of the characteristic curve, and it will require a whole chapter to discuss the best methods of ensuring that this is done.

Commercial plates are usually coated by laying sheets of carefully cleaned and prepared glass on a travelling belt which passes underneath a weir over which emulsion is flowing. Each sheet passes under the weir to receive a uniform layer of emulsion, and then through a chilling

[1] Notice that the density does not increase with exposure in direct ratio, i.e. four times exposure does not produce four times the density, and the density/exposure relationship is more conveniently expressed by plotting density against the logarithm of the exposure.

chamber where the emulsion is set after which the plates are stacked in racks, dried, and cut to size (see Plate 15).

Film, on the other hand, is coated in reels 30–40 inches wide and up to 1,000 feet in length. The film base usually passes from the reel round a large cylindrical drum through which chilled brine is circulating. At the coating station the surface of the celluloid just touches the surface of melted emulsion in a trough beneath the cylinder, the emulsion adhering to the film base in an amount which depends upon the speed of travel and the temperatures of the chilling cylinder and the emulsion. By the time the coated film has completed its travel round the cylinder the emulsion has set, and the film is hung in festoons from the crossbars of an overhead travelling track which carries it down a drying tunnel. The reels of dry film are then slit and spooled in the various sizes.

The white-clad, white-hatted operatives enter the coating room of a modern photographic factory by passing round the light-trapped corners of long passages. Each bay is more dimly lit than its predecessor, so that by the time the air-conditioned coating room itself is reached the eyes have had time to adapt themselves to the very dim light in which the machines are working. Even then, however, it is impossible to do more than sense the scrupulous cleanliness of the surroundings. The photographic industry is second to none in the demands which it makes for cleanliness and purity of materials, and the coating room itself is guarded from any possible source of contamination in a manner that suggests comparison with the operating theatre of a hospital.

negative between the record of the two brightest steps, since each will consist of the same number of developed grains—the maximum obtainable.

Plate 16 shows a scale of tones of the type we have been discussing, and alongside it are shown reproductions of three negatives typical of over-exposed, correctly exposed, and under-exposed negatives.

The correct exposure therefore lies somewhere between the two extremes, of under-exposure where the emulsion does not record the differences between the darker tones, and over-exposure where it does not distinguish between the brightest tones.

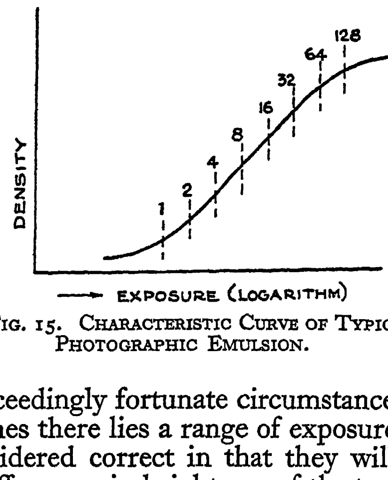


FIG. 15. CHARACTERISTIC CURVE OF TYPICAL PHOTOGRAPHIC EMULSION.

It is an exceedingly fortunate circumstance that between these two times there lies a range of exposures all of which may be considered correct in that they will satisfactorily record the differences in brightness of the tones of ordinary subjects.

This latitude is due to the fact that a typical subject does not include the whole of the large range of brightnesses which a photographic emulsion is capable of recording. Thus, in a landscape picture the brightest portion of the subject—the sky—is usually only about thirty times brighter than the darkest shadow, whereas a good photographic emulsion is capable of rendering on the same scale a brightness range of 130.

These facts are expressed graphically in Fig. 15, which shows the curve characteristic of the relation between exposure given and density obtained in a typical photographic emulsion. The relative changes in intensity of the

exposing light are marked on the curve and it will be seen that lower intensities than 1 or greater intensities than 128 produce noticeably less change of density. The emulsion whose characteristic curve is shown can record a range of brightnesses or intensities of from 1 to 128 and negatives in which the range of densities lies between that given by the intensity of 1 and that given by the intensity 32 will give prints which are identical in tone rendering with those which have a minimum density equal to that given by intensity 4 and a maximum density equal to that given by intensity 128.

These two negatives are identical in so far as tone rendering is concerned, and they can be made visually indistinguishable by binding up the less exposed negative with absolutely uniform neutral grey glass of suitable density.

To compensate for the uniform difference in over-all density between the negatives, it is only necessary to give a corresponding increase in exposure when printing from the second negative, identical prints then being obtained.

Determining Exposure.

If an exposure within the permissible margin of error is to be given, the photographer must take into account four factors: (1) the size of the aperture or stop which is admitting light to the lens; (2) the strength of the light falling on the subject; (3) the nature of the subject, and (4) the speed of the emulsion.

The Size of the Stop. A stop is a sort of tap which controls the actual area of the lens through which light can pass, a small stop allowing less light to pass through the lens in a given time than a large one. When the lens is fitted with an iris diaphragm an infinite number of settings is possible, but for convenience a series of settings is engraved on the lens-mount whose relative apertures are such that the exposure required when using any one of these marked f values is usually half that required with its predecessor. In other words, if you close down one stop you must double the exposure, and if you open up one stop you must halve the exposure if the same amount of light is to reach the plate. The cheapest form of box camera usually has a fixed aperture of value f16, and beginners who possess more expensive models with adjustable stops would be well advised to commence by setting the aperture to f16 and leaving

it there while they gain experience with the remaining factors influencing exposure.

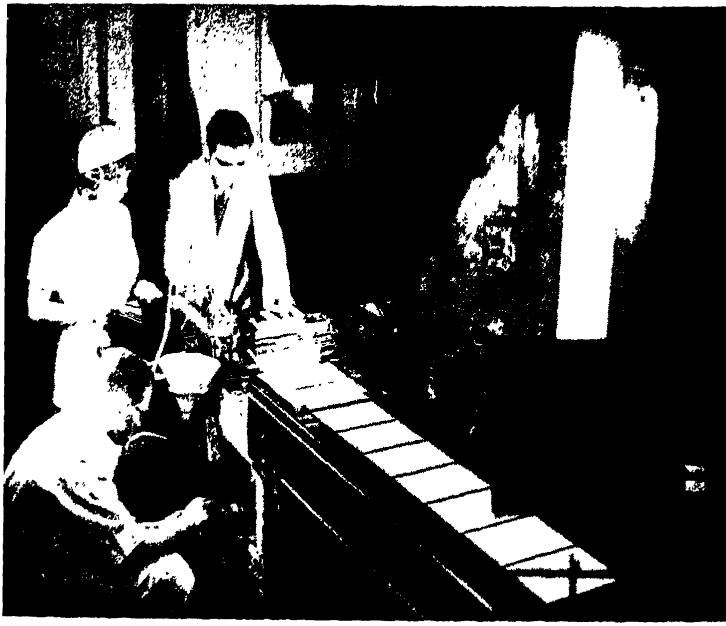
The Strength of the Light falling on the Subject. The amount of light which a subject reflects to a lens will obviously be determined by the amount of light falling upon the subject in the first place. Although the same subject in the middle of an open landscape is more strongly illuminated than if it is situated in the shadow of a wall, in a narrow street, or in a room, the eye is a poor judge of the difference in luminosity in these cases, firstly because it has no fixed standard by which to measure the relative brightness, and secondly because it automatically adapts itself to changing illumination (see Chap. V). As this adaptation is unconscious, visual estimates of the relative brightness of different scenes are misleading. Moreover, the light itself varies in strength, and the same subject in the same environment will require different exposures when the sun is shining on it from a clear sky, when the sun is obscured by clouds, at different times in the day, and at different seasons of the year.

Any one who attempts to judge exposures by simple inspection of the subject is assuming that he can estimate with sufficient accuracy the extent by which the strength of the light differs on these different occasions. He wastes a good deal more material, and the general standard of his results is considerably lower, than that of the photographer who, wisely distrusting his eyes and his memory, relies upon the actual measurement of the light. The various exposure meters and calculators which are available are so simple to use that there is no excuse for their neglect, and sensible beginners will consider one of them an essential part of his equipment.

He has four classes from which to choose, and as full instructions for the use of each are issued by their makers, it is only necessary to deal with them briefly, drawing attention to their relative merits from a rather more detached view-point than can be expected of their manufacturers!

(A) *Chemical Exposure Meters, or Actinometers.* The light falling on a subject is actually measured by means of its chemical action. A typical meter contains a strip of light-sensitive paper, a portion of which can be brought behind a tiny window alongside which is painted a standard tint. The meter is held in a position in which it receives the same sort of light as that falling on the subject. Normally, there-

PLATE 15



An unseen industry: coating photographic plates

The photograph was made by infra-red radiation, and the plates which are seen receiving their light-sensitive emulsion coating, being insensitive to infra-red, were not spoiled

Courtesy of Weekly Illustrated, J. Jarche and Ilford Ltd.

fore, the sensitive paper is exposed to the sky, in the shadow of the photographer's body if the subject itself is in shadow, and the time required for the sensitive paper to darken to the standard tint is noted. By reference to a calculator or table, the time taken for the two tints to reach a match in depth is converted into the time of exposure required.

Such actinometers are cheap, simple, and, when experience has been gained with them, reliable. Since, however, they normally indicate the shortest exposure that will be necessary, it is usually advisable to double the time of exposure they indicate, since over-exposure is a less serious error than under-exposure.

In a very poor light, such as the dark interior of a church, actinometers are more reliable than other forms of meter, though the time taken to obtain a reading is then a disadvantage. This may be offset by choosing a stop such that the time of exposure will be equal to the actinometer time. The exposure is then commenced at the same time as the actinometer paper is uncovered and continued until the standard comparison tint is matched.

(B) *Exposure Tables.* These are based on data obtained from a large number of measurements of the strength of light under various conditions and in various parts of the world. The average values so obtained are tabulated for a particular country in such a way that when the subject, time of day, month, lighting conditions and speed of plate are specified, the probable exposure required in that district is indicated. It will be realized that the use of such tables can only indicate the probable exposure, since it is left to the photographer to interpret his subject in terms of such phrases as 'Portrait in shade', 'Sun obscured by light clouds', &c. On the other hand, tables can be relied upon to give a sufficiently definite answer when the question is whether a snapshot is possible or not, and beginners and those who only use a camera occasionally will find that reference to tables will prevent many a wasted exposure.

Exposure calculators and tables are chiefly of value for determining exposures of the ordinary run of out-of-door subjects. They are untrustworthy guides in bad light and for interior work generally.

(C) *Photometers.* There are many forms of the photometer type of exposure meter, but all depend broadly upon the same principles. The so-called 'Extinction' photometers

are the most popular. In these the photographer looks towards the subject through a grey wedge or graduated filter and, by adjusting this, he reduces the brightness of the image seen through the instrument until it just disappears. The image may consist of the subject itself or a series of numbers. In the latter case it is the number which is only just visible that is taken as the reading.

By reference to tables engraved on the instrument, the setting at which the image is extinguished (or the last visible number) is converted into the probable exposure required. Although these instruments are very fashionable, they are not, on the whole, appreciably more reliable than the much cheaper exposure tables. It has been explained that the eye automatically responds to alterations in the intensity of illumination, and it will be found that the readings given by such instruments depend upon the length of time the observer keeps them to his eye and the brightness of the scene upon which the eye has been looking just before the measurement is made.

To combat this uncertainty it is necessary to allow sufficient time to elapse for the eye to adapt itself to the dark interior of the photometer before taking the reading; but even so, there is a tendency to over-estimate the illumination in poor light, and in such light it is usually safe to give double the indicated exposure.

The following table, compiled from a systematic comparison of a large number of exposure meters over a very wide range of different cases, is some indication of the relative value of these three types of exposure meter (J. Milbauer):

	Successes per cent.	*Semi-successes* per cent.
Actinometers using print-out papers	77	10
Photometers	45	28
Tables and calculators	54	5

(D) *Photo-electric Exposure Meters.* In photo-electric exposure meters light falls upon a layer of copper covered with cuprous oxide or of iron covered by selenium. When the surface where either of these two components meet is illuminated, electric currents proportional to the intensity of the light are generated and cause the deflection of a galvanometer needle. Recently a number of different types, all employing this general principle, have been marketed

in a compact form and are rapidly becoming very popular. A typical instrument is little larger than a match-box. A collecting lens which is pointed at the subject forms one end of the box, whilst the pointer of the galvanometer moves over a scale recessed in the top. The advantage of such meters is that they give an instantaneous measure of the light intensity very much as the eye sees it. Moreover, there is no question of the reading being influenced by the behaviour of the photographer's eye, as may be the case when it is a question of judging tints (actinometers) or bringing the eye to a constant degree of sensitiveness (extinction photometers).

The Nature of the Subject. Even the most expensive exposure meter can do no more than measure the intensity of the light falling upon it—that is, the average brightness of the scene—and the readings which it gives must be interpreted by reference to the tables or ready-reckoners which form part of each instrument.

Photometers and photo-electric exposure meters measure the light reflected from the subject towards the lens, and at first thought it might appear that their readings should therefore be directly translatable into the exposure required. That this is not the case will be obvious if we consider the exposure required for two portraits, one taken against a white background and the other against a black background. If the lighting on the sitter's face is identical, the exposure necessary will be the same in each case, though the meter readings will obviously be different since the mean intensity of illumination from the whole of the field of view is different. Then again, suppose we were taking a photograph in a small clearing in a wood and that through a gap in the trees at the top of the picture the sky can be seen. Assuming that we wish to obtain a correctly exposed negative of the tree-trunks and undergrowth, we must allow for the fact that the meter is not only recording the light coming from the trees, but also from the bright patch of sky. The meter reading will therefore be higher than would be the case if the sky was not in its field of view, even though this might not affect the amount of light actually reflected by those portions of the subject in which we are interested.

In the case mentioned, the difficulty might be dodged by directing the meter downwards so that the sky is not included, but usually it is necessary to divide up subjects into

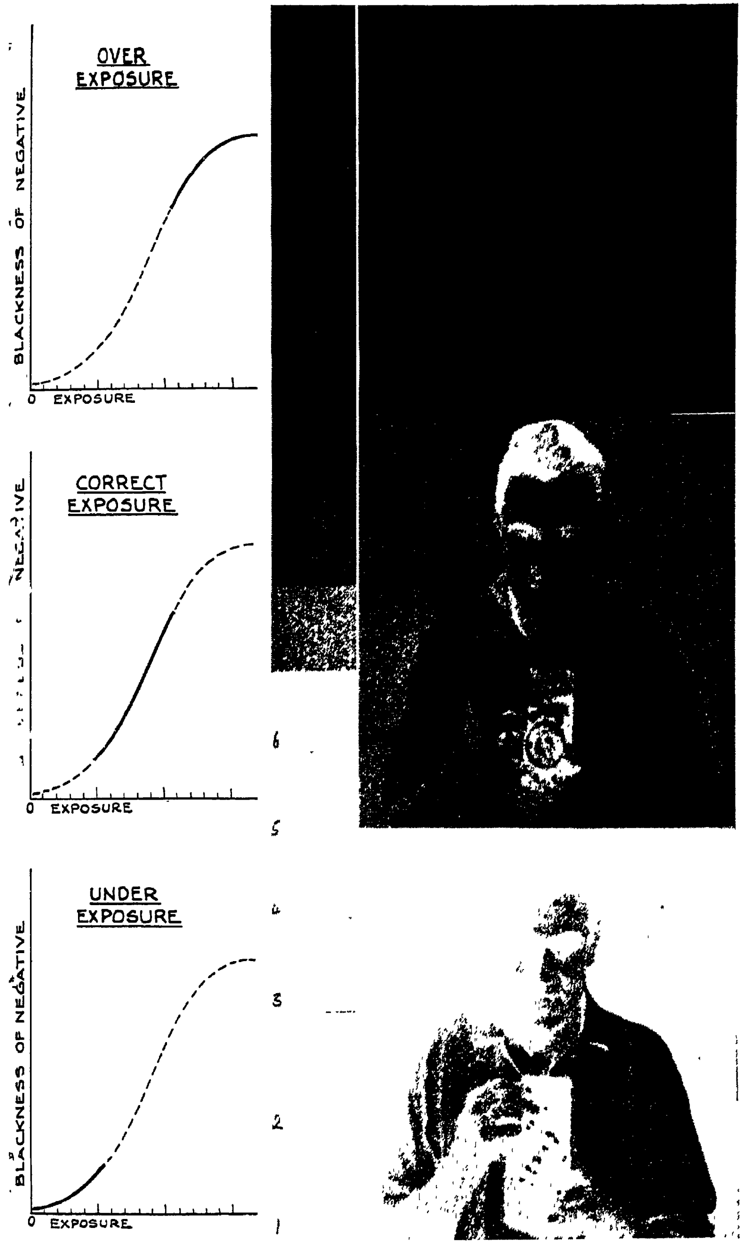
groups as with other meters and apply the correction factor appropriate to each group.

Actinometers and exposure tables, on the other hand, are concerned with the strength of light falling *on* the subject, and even more careful account must be taken of the subject's character in arriving at the exposure to be given.

Generally speaking, the correct exposure is that time which will produce a useful image of the details in the deepest shadow of the subject—hence the maxim, 'Expose for the shadows and let the high-lights take care of themselves'. The rule is not, however, of universal application. Thus, if you were photographing the interior of a church it would be essential that the details of the interior, most of which will be in shadow, should be well rendered in the negative, and even if the exposure which results in this is so long that the windows of the church are over-exposed, as a photograph of the interior of a building the result would be successful. If, however, you were photographing a wide expanse of landscape, the majority of your picture would be brilliantly lit, and if you were to expose, as you did in the church, for such a time that the details in such shadows as exist under nearby trees were well recorded, the result might be a failure because in rendering this shadow detail, you would have over-exposed 90 per cent. of the subject forming your picture.

Accordingly, exposure meters incorporate a table in which subjects are classified into groups, and the correction factor indicated on the meter for the particular group in which the subject falls is applied to the reading. The following is typical of such classifications:

Sea and sky	Give 1/10th of indicated exposure
Snow and glacier scenes Sea views with shipping . . .	,, 1/10th ,, ,,
Distant landscape Panoramas and beach scenes . .	,, 1/8th ,, ,,
Open landscapes (field, river scenes, &c.) Light coloured objects	,, 1/4 ,, ,,
Open landscapes with foreground (minor objects in foreground) . . .	,, 1/2 ,, ,,
Average subjects (buildings, groups, portraits)	,, 1
Heavy foreground (narrow streets) (close ups, portraits, groups under trees, near forest scenery)	,, twice indicated exposure
Woodland scenery (under trees) . .	,, 6 to 8 times indicated exposure
Portrait indoors (6 ft. from window in well-lighted room)	,, 16 times and upwards indicated exposure



The exposure received by each step of the wedge is plotted against the measured density of the step

Venice—Gondolas against the sun *Courtesy of J. Dudley Johnston, Hon. F.R.P.S.*

The classification does not need to be so elaborate in the case of photometers and photo-electric meters, and it is usually sufficient to classify subjects into 'light', 'average', or 'dark'.

The Speed of the Emulsion. The remaining factor of which account must be taken in arriving at the exposure to be given is the sensitivity of the emulsion itself. Immediately we try to define this, however, we find ourselves in difficulty. Sensitivity to what? To sunlight? To the light from a cloudy sky? To electric light? The emulsion whose preparation was described on page 46 is only sensitive to blue light, and the amount of photographic effect with such an emulsion will be determined solely by the amount of blue rays in this light.

We have already noted that white light is a mixture of different coloured rays. Only when these are present in certain definite proportions is the light truly white, and as the sun sinks towards the horizon the proportion of blue light in the rays reaching our subject falls lower and lower —the light becomes visibly warmer in colour.

Electric light is yellowish for the same reason—there is a smaller proportion of blue-violet rays relative to those of the other colours.

Accordingly, the working speed of the emulsion will be different according to whether the photograph is taken at midday, in late afternoon, or in artificial light. Moreover, this difference will still exist even if, to the eye, the visual brightness of the subject under these three lightings is the same, since it is the varying amount of *blue* in the light which is important, and this the eye is quite unable to estimate.

We shall see in Chapter IX that, by treating an ordinary colour-blind emulsion with certain dye-stuffs, it can be rendered sensitive to light of the remainder of the spectrum, and if we compare the speed of two plates coated with the same emulsion, but one of which has been given this additional sensitivity to green, yellow, and red light, it will be found that, whereas at midday in bright light the colour sensitive plate will have perhaps twice the working speed of an ordinary plate, in the evening it will be several times faster owing to the larger proportion of green, yellow, and red rays present when the sun is nearer the horizon; while in electric light, which contains a relatively small proportion

of the violet and blue rays to which both plates are equally sensitive, the difference in speed will be remarkable.

Since, moreover, the working speed of an emulsion depends to a certain extent on the developer employed, it is perhaps not surprising to find that there is no universally accepted system whereby the speed of an emulsion may be expressed.

When a manufacturer commits himself to a numerical rating he gives this in terms of H and D numbers, Scheiner degrees, Watkins factors, or DIN units. The theory of these systems need not concern us—it is sufficient to note that each system is different in principle, and that even when two manufacturers use what is nominally the same system, they frequently employ such widely differing techniques for arriving at the figures they allot their products that the speed ratings given by any particular maker should be taken as referring only to the relative speeds of his own products.

A readily workable, logical, informative, internationally agreed system of expressing working speeds of photographic material is badly wanted.

At this point the reader may be inclined to think that any attempt at increasing his present average of successful exposures is a hopeless task. That a possibly misleading exposure meter reading can be converted into a correct exposure time by combining it with an arbitrary classification of the subject and an untrustworthy speed rating of the emulsion seems highly improbable. Actually, the tables forming a part of most exposure meters are so drawn up that they will take into account many of the peculiarities of emulsion sensitivity, while the speed rating given by reliable manufacturers generally represents quite satisfactorily the average properties of each type of material he issues. It is only under exceptional circumstances that meters and speed ratings are noticeably untrustworthy.

It will be convenient at this point to draw attention to the fact that, although manufacturers are accustomed to making the speed of their products the basis of their advertisements, excessively high speeds are often obtained at the expense of more desirable qualities, particularly gradation—the power of rendering satisfactorily a large number of tones; and, other things being equal, the average speed emulsions are more satisfactory for pictorial work.

If the beginner is not to flounder about gradually growing

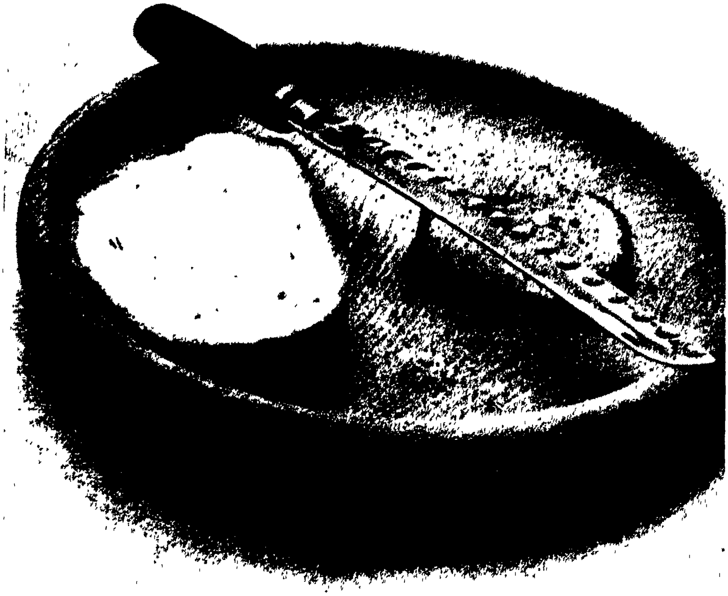
accustomed to the idea that 25 per cent. of any photographs he takes will be spoilt by incorrect exposure, and half the remainder will be worse than they need be for the same reason, it is a good plan to start his photographic career by using a couple of spools of film and an exposure meter in experimenting systematically with the problem. Whichever form of exposure meter he decides to rely on when fully experienced, he would be well advised to commence with the actinometer type, in which the strength of the light is determined by noting the time taken for sensitive paper to darken to a tint mounted alongside.

He should expose one spool of film on a series of typical subjects, e.g. a portrait in the sun, a portrait in the shade, a landscape, a street scene, and an interior, in each case exposing in accordance with the reading given by the actinometer when used in the manner specified by its maker, a record being kept of the actinometer reading, the exposure given, and the stop used. In the case of the interior, it would be a good plan to make two exposures, one of which is double the time indicated by the actinometer. Now have this film developed. A beginner would be well advised to send his first attempts to a processing firm, postponing the fascinating business of developing his own films until he has mastered the exposure problem. Most processing firms send a brief report on films they develop, and an examination of the negatives in the light of this report will enable the novice to determine whether it would be desirable to repeat the whole series again. If, for example, all the results are under-exposed, it is probable that the speed of the emulsion has been over-estimated. If, on the other hand, the exposures are 'all over the shop', it is fairly certain that the actinometer is not being used in the proper manner and its instruction booklet should be studied afresh. In any event it is desirable to keep to one type of photographic material by one manufacturer until the problem of exposure has been mastered. It would be invidious to single out any particular make of film for special recommendation. The products of the reputable manufacturers are all excellent—the rival brands in each class being very much alike—notwithstanding claims to the contrary which may form the basis of their advertisements!

Those people who do not take photography seriously enough to make a study of exposure along systematic lines

will find that it is hardly worth while to own a camera costing more than a few shillings. If they ask the dealer who sells them their films to load these into the camera and only use the camera on subjects on which the sun is shining brightly, giving the snapshot exposure, they can count on getting five out of every six negatives reasonably well exposed.

Such people are not, of course, photographers, though they will get a lot of pleasure out of their cameras. On the other hand, those who want to be something more than casual snapshotters and do justice to any camera costing more than a shilling or so should most certainly buy an exposure meter and use it.



Bread
Courtesy of Gilbert Cousland, F.R.P.S.

Photographer and young *Courtesy of J. H. Ahern, F.R.P.S.*

CHAPTER VII

PROCESSING

Exposure in the camera does not produce a visible change in the emulsion, and in order to convert the exposed plate into a negative it must be developed—that is, it must be treated with solutions which are capable of distinguishing between the light-struck and the unexposed grains of silver bromide by removing bromine from the former and converting them into metallic silver. Many substances are very ready to combine with bromine and will decompose silver bromide, but they are not necessarily suitable as developing agents because they attack exposed and unexposed silver bromide grains with equal ease.

There is, however, a limited number of relatively mild reducing agents which just fail to reduce the silver bromide of a photographic emulsion unless it has first been made unstable by light. Typical of these mild reducing agents is an alkaline solution of pyrogallol—a feathery white chemical obtained by distilling gallic acid derived from gall nuts or 'oak apples'. If a solution of pyrogallol in sodium carbonate is poured on to the precipitate of silver bromide obtained by mixing solutions of silver nitrate and potassium bromide, the cream-coloured mass turns black owing to the liberation of metallic silver throughout the mass. When, however, the silver bromide is embedded in gelatine as in a photographic emulsion, it is less easily attacked by the alkaline pyrogallol, the gelatine layers acting like a sort of defensive armour to each grain, and, providing the experiment is carried out in the dark, an unexposed photographic plate must be immersed for some considerable time in this solution before any appreciable conversion into metallic silver is detectable.

On the other hand, if the emulsion has previously been exposed to light, in some way whose mechanism is still a mystery the grains are rendered unstable, and the pyro solution which is just unable to reduce the unexposed grains attacks those that have been light-struck and converts them into metallic silver. This conversion is not, of course, instantaneous, and the time required to change all the light-struck grains depends upon the strength of the solution, the temperature, and the composition of the developing bath.

The course of development is shown in diagrammatic form in Fig. 16: (1) represents the top view of an emulsion, the individual grains of silver bromide being shown many thousand times larger than their actual size. A scale of four tones, white, light grey, mid-grey, and black, has been photographed on this emulsion with the result that different parts have received different amounts of light. Section *D* has received a full exposure, section *A* no exposure, and sections *B* and *C* intermediate exposures. If we could now watch the progress of development we should see the emulsion pass through the stages shown diagrammatically in the subsequent figures; (2) shows the appearance when one-quarter of the development is complete—one-quarter of the light-struck particles in each tone have been reduced to black silver; (3) shows the half-way stage—one-half the affected grains are now blackened; (4) shows the final stage, when all the silver particles which have been rendered developable by exposure have been blackened. If the treatment with developer is carried beyond the point where all the exposed grains have been reduced to silver, it will, in many cases, begin to attack the unexposed grains since, as has been pointed out, these are only relatively less susceptible to reduction than the exposed grains. As a result, over-development will result in a veil of 'fog' over the whole negative, and if this is appreciable there will be a less obvious difference between each tone.

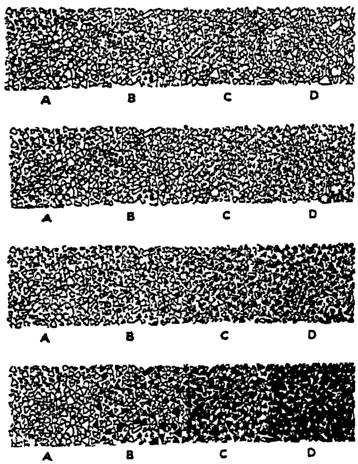


Fig. 16

If Fig. 16 is examined through half-closed eyes it will be noticed that, as development proceeds, not only does the image get darker, but the difference between each step becomes more clearly visible. Indeed, if development is unduly prolonged, the contrast between each step may become greater in the negative than it is in the subject photographed.

Although this illustration gives a crude picture of the appearance of a layer of emulsion during development, a better idea of the changing relationship between the tones is obtained by plotting the course of events graphically.

Suppose we divide up a piece of squared paper into four equal area sections each representing one of the four tones photographed. If we assume that the squares themselves represent grains of silver bromide, we can indicate by a dot

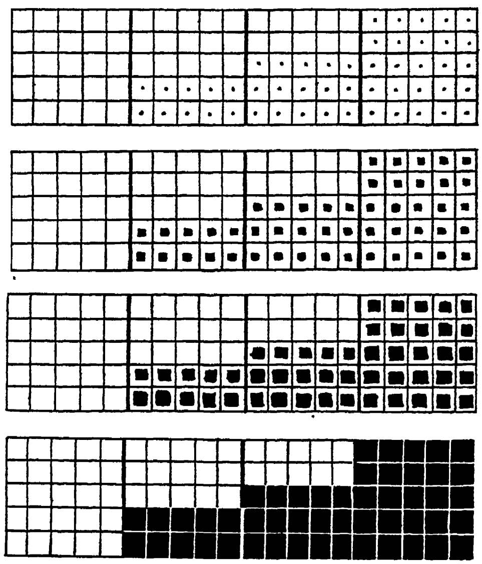


FIG. 17

those grains which have been made developable by light. There will therefore be no dots in the area representing the photograph of a dead-black paper, and the largest number of dots in the area representing the white paper which reflected most light into the camera (Fig. 17). The course of development can be shown by blackening in each square as the grains it represents is reduced to silver. In Fig. 18 these stages in development are shown graphically, the steps being marked off along *AC* while the number of black grains in each step—or what amounts to the same thing—the blackness or density of each step, is shown along *AB*.

It is obvious that in this graph the greater the difference

in density between the first and last step (that is, the greater the contrast between them) the steeper the slope, and it will be seen that although the growth in contrast is rapid in the early stages of development, it slows up with time until a point is reached where further treatment with developer is without effect on contrast.

Just as in exposing the photographer aims at obtaining a suitable difference in light action for the different tones of the subject, so in development he must aim at obtaining the correct contrast between these tones. If the negative is under-developed there will be insufficient differentiation between the tones, and prints from such a negative will therefore be lifeless and muddy; whereas over-development will result in an exaggerated contrast, and the resulting print will be of the 'soot and whitewash' type.

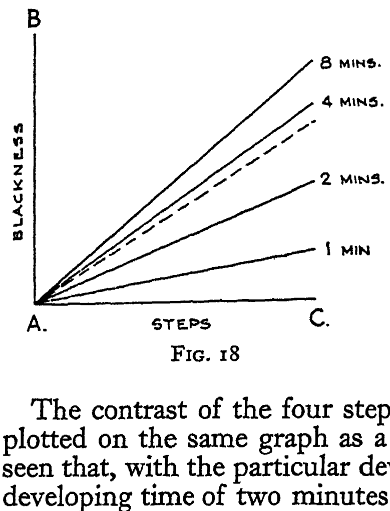


FIG. 18

The contrast of the four steps of the original subject is plotted on the same graph as a dotted line, and it will be seen that, with the particular developing conditions used, a developing time of two minutes gave a result which was of lower contrast, while eight minutes gave a too contrasty or 'hard' result.

Fortunately it is relatively simple to keep the contrast of the majority of exposed negatives within permissible limits by developing every exposure for a definite time at a definite temperature in the chosen developing solution. There are many possible formulae for the latter, but generally speaking they all have four essential constituents—the developing agent itself, an accelerator, a preservative, and a restrainer.

The Developing Agent. This may be one or more of a variety of organic chemicals of similar type. The most popular developing agents are pyrogallol, metol, and hydroquinone, and these are frequently used in conjunction. Metol, for example, gives under normal conditions images which are full of detail but of rather low contrast, whereas

hydroquinone gives contrast rather than detail. A combination of the two combines the advantages of both.

The Accelerator. A simple solution of the developing agent in water is not a very suitable developer, its action being too sluggish. Addition of an alkali such as sodium carbonate (a pure form of washing soda) acts like the addition of sails to a boat. Whereas a solution of pyrogallol in water will not completely develop an exposed plate in twelve hours, the addition of sodium carbonate speeds up its action so much that development is completed in a few minutes.

The Preservative. Immediately, however, that we make the pyrogallol solution alkaline it will begin to discolour. The darkening begins at the surface of the solution where it is exposed to air, the oxygen of the air combining with the pyrogallol to give a dark-coloured compound. In a relatively short time all the pyrogallol—and hence developing activity of the solution—will be destroyed. Accordingly, the third essential constituent of a developer is a preservative—usually sodium sulphite. Whereas pyrogallol combines with the oxygen of the air or the bromine of the exposed silver grains with equal readiness, sodium sulphite combines only with the oxygen, and it does this with such avidity that any oxygen entering the solution is immediately 'snapped up' and has no opportunity of destroying the developing agent.

The Restrainer. It has been explained that the developability or otherwise of any particular grain is a question of degree. If an unexposed plate is left for a long time in a developer all the grains will eventually be attacked. A very active developer will frequently commence attacking unexposed grains during the period necessary for development of the exposed grains, resulting in the production of an over-all veil of fog. The activity of such developers is therefore reduced by adding a restrainer—potassium bromide. Development is somewhat slower when a restrainer is used, but, on the other hand, the attack on unexposed grains is delayed beyond the time required for production of satisfactory negatives, and the risk of fog is therefore reduced.

To summarize: Photographic developers are solutions that will distinguish between exposed and unexposed silver bromide grains by converting the former into black metallic

silver. In order that this conversion shall proceed at a reasonable speed an alkali is present, discoloration and decomposition of the alkaline developer by oxygen of the air having been prevented by the presence of a relatively large addition of sodium sulphite. In order to avoid the risk of the developer attacking unexposed grains with the production of fog, small amounts of potassium bromide are added. A typical formula for such a developer is:

Pyrogallol	Developing agent	0·5 gms.
Sodium sulphite crystals	Preservatives	5·0 ,,
Potassium metabisulphite crystals		0·5 ,,
Sodium carbonate crystals	Accelerator	5·0 ,,
Potassium bromide	Fog preventer and restrainer	0·06 ,,
Water		100 c.c.

Although the various possible modifications of this formula make pyrogallol the nearest approach to a universal developing agent, to get the best obtainable results when using such specialized products as fine-grained emulsions for miniature camera work, &c., it is necessary to use specialized developers; and readers are referred to one of the many excellent books on practical photography for descriptions of such developers, and to the various manufacturers' instructions for compounding and using the developers they recommend for their products.

Development. With the exception of the brief moment of exposure in the camera, the photographic emulsion must not be exposed to actinic light until after the negative has been developed and fixed. Accordingly, development preferably takes place in absolute darkness, though in the case of the so-called 'ordinary' and 'orthochromatic' materials, which are relatively insensitive to red rays, a limited amount of deep red light is permissible in the dark-room.

In the early days of photography it was customary to examine the plate occasionally during development, leaving it in the solution until inspection by the dim light of the dark-room lamp suggested that the required degree of contrast had been obtained—a risky and uncertain procedure which is nowadays rarely necessary. The practice grew up because it was generally believed that it was possible to correct for errors in exposure by variations in the development times. This, however, is not the case. It is true that if the photographer knows before he commences development that a particular plate is over- or under-exposed, he can by the use of a modified developer partially compensate

for the error, but the possibility of improvement is lost if development has already been commenced with the normal developer, and is negligible if the error in exposure was gross.

A little thought will show that the commercial developing and printing firms could not, at the prices charged, process the thousands of amateur films they receive by the method of inspection, even if the presence of six or eight exposures on every film did not render individual treatment impossible. Accordingly, the films are all developed for a fixed time at a standard temperature (usually 65° F.); and quite apart from its convenience, it has been established that this procedure leads to a higher average of printable negatives being obtained than methods based on inspection. The time required depends upon the nature of the developer, its concentration, and the type of emulsion. A list of development times at different temperatures with recommended developer formula will be found on the instruction pamphlet issued with each manufacturer's negative material.

Not only is the 'time and temperature' method of developing the most universally satisfactory, it also enables the amateur to dispense with a dark-room, since special tanks are sold into which the film can be introduced in daylight. The spool of exposed film is placed in a small light-tight box, and an ingenious arrangement of claws and spindles enables the film to be wound up inside a light-tight apron, which is then removed to the developing tank proper. The developer (but not daylight, which cannot turn dark corners) is able to penetrate into the inner coils of the apron, where it meets the film, and after the proper time has elapsed the developer is drained off and the fixing solution poured in in its place.

Fixation. After the negative has been developed, the unchanged, unexposed silver bromide must be dissolved away. The plate is therefore transferred to a strong solution of sodium thiosulphate (or 'hypo'), which is an excellent solvent for the insoluble silver halides.

A strong solution (40 per cent. is about right) is necessary because most negative emulsions contain a small proportion of silver iodide in addition to silver bromide, and the iodide is only readily soluble in concentrated hypo. In such a solution fixation is complete within five or ten minutes, the creamy appearance of the negative disappearing at about half time.

Unlike the developing solution, which is best used once only, the fixing bath can be used a number of times, but should be discarded immediately it is seen to be working more slowly. A more reliable indication of the limit of usefulness of a fixing bath is to place a drop of it on a piece of blotting-paper and expose it for a few minutes to strong daylight. If the drop turns brown the bath is exhausted.

The silver bromide dissolved out from the plates combines with the sodium thiosulphate to form soluble silver thiosulphate and sodium bromide. With repeated use of the fixing-bath a considerable amount of these compounds accumulates in the solution and its fixing properties are impaired. There is usually no visible evidence that this is the case except the increased time required for fixation, but the use of an exhausted fixing-bath will result in stains appearing on the negatives at a later date, just as they did on the blotting-paper in the test mentioned. Accordingly, most amateur workers throw away the fixing-bath at the end of the day, since the cost of replacement is negligible. Large users find it worth while to recover the silver from discarded fixing-baths, while some motion picture companies not only recover the silver but actually regenerate the original sodium thiosulphate. In the recovery plants used in Hollywood an electric current is passed through the spent fixing-bath, whereupon the silver in solution is electroplated on to the anode and removed for refining and further use, while the sodium thiosulphate is regenerated, the silver-free solution being returned to the film-processing plant.

It is interesting to note that when this system was finally perfected the price of silver was so low that it would not have been worth while to install the recovery plant merely for the sake of the silver. On the other hand, such enormous quantities of thiosulphate are required annually by the motion picture industry that the possibility of using one charge almost indefinitely was in itself a sufficient inducement to adopt the system!

Washing. When fixation is complete the negative must be washed to free the gelatine from soluble salts. If it were dried immediately after removal from the fixing-bath, the hypo would crystallize out in the film. Moreover, the washing must be thorough because, in addition to the hypo, the bath contains soluble silver thiosulphates which will decompose with time into silver sulphide (familiar as the

The Hiker

Courtesy of Studio Briggs, Ltd.,
R. Milwood, A.R.P.S.

'Faithful' Courtesy of Bertram Senkinson, F.R.P.S.

'tarnish' which forms on silver—particularly egg-spoons) and stained and faded negatives would result.

The time required to wash photographic material—plates, films, or paper—depends largely on the efficiency of the washing device. An ordinary glass negative is sufficiently washed if held under a running tap for three or four minutes, a film in slightly longer time, while a fairly substantial paper print will require from ten to fifteen minutes under these conditions. This is quite the quickest way of washing photographic material because a constant supply of fresh water is sweeping over the surface and removing the salts out of harm's way down the sink. On the other hand, it is not a convenient way of washing, and dishes or tanks are usually employed. The efficiency of such washing apparatus varies surprisingly, and a plate which requires a few minutes under a tap may require an hour in a patent washing tank to reach the same freedom from fixing salts. This is because the salts diffusing out from the gelatine film into the water are not immediately swept away by fresh water, but remain in the washing apparatus to contaminate the incoming wash water. In fact, the majority of the washing time required is spent not in washing the photographic material but in washing its container!

A simple method of determining the efficiency of any proposed washing device and finding the time required to wash negatives or prints in it is as follows. For every square inch of photographic material it is proposed to wash at any one time take 1 c.c. of 5 per cent. potassium permanganate solution. Add this to the vessel and note the time required for the water flowing through it to become colourless. In the case of plates and films add five minutes to this time, and you have the number of minutes required to wash your negatives free from hypo. Thus, if a dish is to be used to wash four $3\frac{1}{2} \times 2\frac{1}{2}$ in. plates, the area of the surface to be washed is 35 square inches. Add 35 c.c. of 5 per cent. potassium permanganate to the dish, and assume that in ten minutes every trace of pink colour has disappeared from the water. Then, with the water flowing at the rate used in this experiment, it will require $10 + 5 = 15$ minutes to wash the four negatives.

In the case of photographic papers, this test is not so reliable since the thicker types of paper do not release the fixing salts as readily as does the thin gelatine layer of

negatives, and moreover, if the prints lie on top of one another, the escape of the salts into the solution will take an even longer time. The best plan with papers is therefore: (1) To use *two* fixing-baths, the second of which has been freshly made up. This ensures complete fixation, and a minimum of the dangerous silver salts being carried over to the wash water. (2) Never wash the prints for less than half an hour. (3) Test the print itself for hypo by removing it from the wash water and allowing it to drain into a white cup containing water just tinged pink with potassium permanganate. If hypo is still diffusing out from the print the colour of the permanganate will be immediately discharged, for hypo combines with permanganate to form colourless compounds.

When the material has been washed it is dried in a dust-free atmosphere. Heat is neither necessary nor desirable for amateurs' negatives, and an uneven rate of drying will result in patches of uneven density marring the finished negative.

Films can be hung a few inches apart on a line, wooden clothes-pegs being clipped to the free ends to prevent the films curling up or blowing on to one another in a slight draught. Glass negatives should be placed at least 1 inch apart in a drying rack (see Plate 21) or with the glass side resting against pairs of nails driven into a wooden board.

After-treatment of Negatives. The ideal negative is one which, having received the correct exposure, is properly developed to a degree of contrast suitable for the printing process to be employed. It sometimes happens, however, that, owing to unforeseen circumstances, the negative is far from ideal, and several text-books are devoted entirely to descriptions of methods by which indifferent negatives can be improved. Generally speaking, the amateur rarely finds it worth while to do more than correct errors in his processing technique.

Very little can be done to correct gross errors in exposure, but errors in development can be rectified by chemical treatment of the negatives. If development has been too short, the weak silver image can be intensified by treatment with solutions which, by depositing metal (usually mercury, silver, or chromium) on the silver grains, cause them to grow in size until the image has attained a suitable density. On the other hand, over-development, which will result in a contrasty and probably very dense negative, requires that some of the unwanted silver be dissolved away. Here again there

are many different formulae available, some of which will reduce the density generally, resulting in a shortening of the printing time required. Others will dissolve silver preferentially from the high-lights,[1] and so increase contrast, or from the shadows, reducing contrast.

It should be clearly understood that although intensification will make a thin, weak-looking negative dark and vigorous, it cannot add detail to an under-exposure. Indeed, intensification of an under-exposure which has been developed by inspection rather than by the time and temperature method usually does more harm than good since, when negatives are developed by inspection, there is a great temptation to prolong development of under-exposures in the hope of bringing up detail which has not been recorded. The only result of such lengthy development is to produce a contrasty negative. Subsequent intensification will merely increase this contrast and add to the difficulty of obtaining a satisfactory print. Similarly, when, owing to over-exposure, the negative darkens very rapidly during development, many amateurs foolishly cut short the development time in the hope that they will prevent the detail which they saw appearing being clogged up and lost in the general blackening which follows. As a result, such over-exposed, under-developed negatives will be lacking in contrast and stand in need of intensification rather than reduction! It is for these reasons that the amateur is strongly recommended to commence by time and temperature methods of development, postponing the pleasure of watching the image appear until he prints from his negatives.

Various methods are available for improving the negatives in other respects, usually by hand treatment. Thus the professional portrait photographer frequently makes radical alterations to the straightforward record given by the camera. With a knife he will scrape away portions of the silver image, and so modify outlines even to the extent of altering the shape of the face, removing double chins, blemishes, and so forth. With a pencil he can fill in shadows and remove wrinkles. Obviously such after-treatment is highly skilled work demanding a knowledge of art and anatomy rather than the principles of photography, which is our present concern.

[1] High-lights—the darkest portions of the negative—so called because these correspond with the lightest portion of the print, the finished picture.

CHAPTER VIII

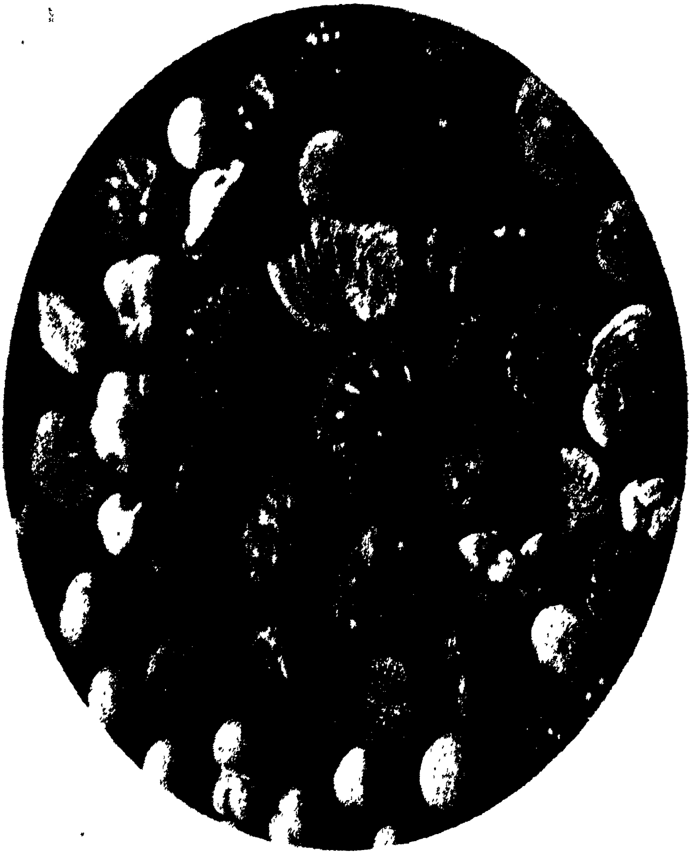
PRINTING PROCESSES

In a photographic negative the record of light and shade is inverted, since the various degrees of brightness of the object photographed are recorded as corresponding degrees of blackness owing to the opacity of the silver deposit obtained as a result of light action.

In order to obtain a picture in which the relationship of light and shade corresponds with that of nature, the negative is printed on to a sensitive paper, when a second inversion takes place and a 'positive' image is obtained.

In Chapter III it was pointed out that a suitable printing material could be made by coating an ordinary silver bromide emulsion on to paper. When the negative is placed in close contact with this 'bromide' paper (emulsion surface to emulsion surface) and exposed to light, the light penetrates the negative in proportion to the varying transparency of the silver deposit and renders the underlying silver bromide developable. If the exposure has been of the right duration (usually a matter of a few seconds only at 4 or 5 feet from a 20 candle-power electric lamp) the darkest portions of the negative (recording the brightest portions of the subject photographed) will prevent the light from reaching the bromide paper. These areas will therefore be white in the finished print. Underneath the transparent areas of the negative (corresponding to the darkest portions in the subject) there will be maximum light action in the bromide paper, and hence maximum blackness will be produced in these regions on development. The light and shade of the print will therefore be the converse of that in the negative and correspond in its disposition with that of the original.

The silver emulsion used for coating bromide paper is less sensitive to light than the emulsions used for making negative material, but even so, if the material is not to be fogged it must only be handled in orange light, and the exposures required when making contact prints under normal conditions are often inconveniently short for the amateur. Accordingly, bromide paper is chiefly used for producing enlargements where its relatively high sensitivity offsets the low illumination efficiency of convenient forms



Foraminifera Courtesy of *Ranald Rigby, F.R.P.S.*

ᒣortion of motion picture of finish of London to Melbourne Air Race, transmitted by radio frı
ᕕustralia to England *Courtesy of Gaumont-British Pictures, Lt*

of enlarging apparatus. The negative is placed in a projection lantern in the dark-room and the enlarged image is focussed on a white card. An orange filter, which cuts off the blue rays to which the bromide paper is sensitive, is placed in front of the lens while the sensitive paper is substituted for the card, and then exposure is made by moving the filter aside. In order to determine how long this exposure should be it is a usual plan to commence by making a series of trial exposures on a strip of the paper. To do this a shield, such as a piece of card, is placed between the lens and the bromide paper, the shield being moved at definite times during the exposure so that it covers an increasingly greater area of the printing paper. In a typical trial a series of exposures ranging from 5 to 80 seconds would be made by first exposing without the shield for 5 seconds. Then, with the shield covering roughly one-fifth of the paper surface, the exposure is continued for another 5 seconds. The shield is now moved forward at successive intervals so as to cover an additional area at intervals of 10, 20, and 40 seconds. Strips of the paper will then have received exposures as follows:

5 seconds—5 seconds
5 plus 5 seconds—10 seconds
5 plus 5 plus 10 seconds—20 seconds
5 plus 5 plus 10 plus 20 seconds—40 seconds
5 plus 5 plus 10 plus 20 plus 40 seconds—80 seconds

It will be noticed that each section has thus received twice the exposure of its predecessor.

Both in exposing negatives in the camera and making prints on paper, there is seldom any point in altering exposure by less than an amount equal to half or twice the incorrect value, since nothing less than alterations of this order will have an appreciable effect on the density of the image.

Inspection of the trial strip after development will indicate which of the various exposures is most likely to give a pleasing print of the whole negative.

Only a few of the developers available for negative making are suitable for developing bromide prints. In a negative the colour of the image is immaterial, since the negative is only a means to an end, and providing the silver deposit will stop light it does not matter whether it is dead black

or not. Pyrogallol, for example, gives a brownish silver image and an all-over yellowish tinge to the gelatine of the emulsion which, whilst of no importance in a negative, renders Pyro an unsuitable developer for paper prints where a good black and white image and an unstained background are required. Metol-hydroquinone or amidol are the usual bromide print developers, and that exposure is correct which gives the best result after a developing time of two to four minutes in the formula recommended by the manufacturer.

Gaslight Paper. Emulsions of silver chloride in gelatine are more than one hundred times less sensitive to light than silver bromide, and they form the basis of the so-called 'Gaslight Papers'. As the name is intended to imply, gaslight papers can be safely handled in weak artificial light, and as no special dark-room is necessary, these papers are a very convenient printing medium for amateurs. A typical way of working with gaslight papers is to use a room lit only by a table-lamp. A small screen, such as a drawing-board, is arranged to prevent direct rays of light from falling on that section of the table where the printing frame is loaded, and the exposed paper is developed in the shadow of this screen. The negative is placed in the frame, the coated surface of the gaslight paper being placed face to face with the gelatine surface of the negative. The back of the frame is then secured in position by spring arms whose tension ensures the closest possible contact between the two surfaces. The loaded frame is now brought out of the shadow of the screen and placed in the exposing position, say 12 inches from the filament of the lamp. The length of exposure is determined by means of a trial exposure given by means of the movable shield described under bromide printing. If the lamp is 25 candle-power and the negative of average density, trial exposures from 20, 40, 80, and 160 seconds would be a normal series.

The trial exposure is developed in the developing solution recommended by the maker of the paper, and then, if necessary, a second trial is made at a greater distance from the lamp if all the exposed strips are too dark, or nearer the lamp if a satisfactory result is only obtainable with the longest exposure.

Once the time of exposure required to print a typical negative under the conditions you are using has been found, it is not difficult to judge by inspection of subsequent

negatives what modification will be necessary when printing them.

The time of development of gaslight papers is very short —of the order of 20 seconds—and if the image is not dark enough at the end of this period the exposure must be increased, since any attempt to bring out detail by longer development will result in the shadows of the print becoming blocked up, while the paper itself will probably be stained. The developer can be used for several prints in succession, being discarded as soon as it becomes discoloured or is obviously losing its activity. The developed prints are given a quick rinse in water and transferred to a fixing-bath, which has preferably been rendered slightly acid by the addition of a little potassium metabisulphite. Most manufacturers sell at least three grades of gaslight and bromide papers: (1) vigorous, for printing from low contrast or under-developed negatives; (2) normal, for average negatives; and (3) soft, for contrasty or over-developed negatives. These grades are necessary because, unlike a negative, the contrast of a print on paper cannot be altered by altering the development time. This is because, in the case of a print on paper, contrast is judged by visual appearance of the print when viewed by reflected light; and whereas in a negative every increase in the number of grains of developed silver will result in less light being transmitted, once we have produced on a paper surface a layer of silver which looks dead black, any further addition of silver cannot make the surface appear blacker. When, therefore, in a paper print this limiting blackness has been produced, further development will only darken the lighter tones, and the print will appear 'muddy' or clogged up rather than of greater contrast. In other words, the contrast may be there, but we can only see that this is so if we look *through* rather than *at* the print. We can nevertheless make use of such hidden contrast in a curious method of printing which finds application when it is necessary to copy plans, drawings, pages of books, &c., and it is not convenient or possible to photograph them with a camera. It has been pointed out that a very contrasty print owes its 'soot and whitewash' appearance to the fact that it renders a very short scale of tones between black and white. If a contrast bromide paper is developed in a developer which accentuates this contrast still further, the range of tones can be so restricted that if two exposures to light are

given, one of which is twice the other, the full exposure will develop to complete blackness when the half exposure will develop scarcely any image at all.

A sheet of bromide paper is laid face downwards in contact with a black-and-white design and exposed to light so that the light passes through the sensitive paper before it reaches the design to be reproduced. It is obvious that the whole of the sensitive paper will be fogged, and the eventual production of a usable image depends on the fact that where the light, after passing through the bromide paper, meets the white surface of the original, it is reflected back through the sensitive coating, which thus receives two exposures, one from the light on its way to the original and the second from the light on its way back. But where, however, the light after its first passage through the bromide paper meets the black surface of the design or type matter on the sheet being copied, it is absorbed, and so a second exposure by reflection from the surface beneath does not occur. On removing the bromide paper from the design, therefore, the emulsion in contact with the white reflecting surface of the original had received nearly twice the exposure of the emulsion in contact with the black design, and a developer loaded with restrainer will emphasize this difference. The paper negative so obtained can be oiled to render it transparent and although when examined by reflected light it may appear muddy and clogged, it can be used for printing further copies of the original.

Printing out Papers. Although the majority of modern photographs are made on 'bromide' and 'gaslight' papers in which a latent image formed by relatively short exposure to light is developed to give the final image, the earliest types of printing paper depended upon the production of a visible image by exposure to light alone. Considerably more light is required for such P.O.P. papers (as they are called for short), since the function of the light is no longer confined to making a silver halide grain unstable—it must actually break up the silver compound. A crude form of P.O.P. paper can be made by floating sheets of writing-paper on a solution of common salt or sodium chloride and then on a solution of silver nitrate. The silver nitrate reacts with the sodium chloride to produce within the surface of the paper a white precipitate of light-sensitive silver chloride. When this sensitized paper is exposed to strong daylight the surface

darkens owing to the liberation of finely divided metallic silver, and the action could be represented as

Silver chloride + Light → Silver + Chlorine.

However, if silver is exposed to chlorine vapour the metal is attacked with the formation of silver chloride, and so, unless the chlorine liberated on light exposure is rendered inactive as fast as it is formed, a stable image would not be obtained, for the silver and chlorine would recombine as soon as the light ceased to act. As it happens, however, the chlorine liberated in P.O.P. paper readily combines with organic matter present in the paper fibres, and with the excess of silver nitrate that will be present in the paper if a sufficiently strong solution of this substance is used in the order given. Substances that will combine with the chlorine liberated by light and so prevent its recombination with the silver are called 'sensitizers', and modern P.O.P. papers are not, of course, prepared by the primitive flotation process described, but are emulsions of silver chloride in gelatine to which suitable sensitizers are added before coating on to paper by machinery similar to that used for coating roll-film emulsions.

Since such papers give a visible image on exposure (which is of the order of from five to ten minutes in ordinary daylight) the progress of printing can be judged by inspection, and these papers are therefore popular with amateurs who do not feel inclined to acquire the somewhat more complicated technique of making 'gaslight' prints.

When the brownish-red image on the paper is somewhat darker than is actually wanted in the finished result, the paper is transferred to a plain hypo fixing-bath. During fixation the image becomes slightly lighter—that is why it requires to be overprinted—and if a plain silver chloride paper has been used the fixed image will be a sickly yellow-brown colour—the colour being due to the fact that the image in print out papers consists of silver in an extremely fine state of subdivision, the individual particles being considerably smaller than the blackened grains which form a developed silver image. The colour of the silver deposit depends very largely on the size of its individual particles, and the smaller the size, the farther away from black is the colour of the image. This phenomenon is quite general, most people being aware, for example, that the rich ruby

colours in a stained-glass window are due to gold in a very fine state of subdivision (colloidal gold).

Accordingly, to convert the unpleasant yellowish colour of the P.O.P. into a darker, more acceptable shade, the particles must be increased in size by treating the print with a substance capable of combining with the silver to form large particles. Gold salts were commonly used for this purpose, the combined silver-gold image varying in colour from a rich brown to a cold purple. Nowadays the manufacturer includes these toning constituents (gold, selenium, and tellurium compounds) in the sensitive coating, and such papers are therefore called 'self-toning'.

Toning. Since the earliest forms of printing paper were of the P.O.P. type, the brown-purple colour of such prints became so closely associated in people's minds with photographs that the black image obtained with the development type of printing paper had to overcome a good deal of prejudice. The public could not at first be persuaded that a black-and-white picture could be a real photograph, and methods were sought for converting the new black silver images obtained with development papers into the more familiar sepia. Fortunately, silver sulphide in finely divided form is brown and insoluble, and the black silver image can be converted into a brown silver sulphide image by first converting the silver to silver bromide and then treating this with a solution of sodium sulphide. By somewhat similar methods, i.e. conversion of the silver image into a silver salt capable of reacting with various metallic compounds, it is possible to produce images in a number of colours, but the processes are tricky to work, the results are frequently impermanent, and only sulphide toning to give brown images has attained any real popularity.

When a coloured image which shall be permanent is wanted it is usual to use an entirely different form of printing process known as 'carbon'.

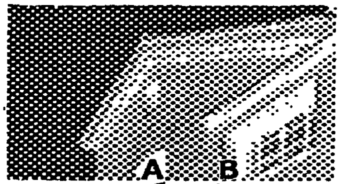
Carbon Printing. Although the compounds of silver are of pre-eminent importance in photography, there are many other substances which are altered by light, and which can be employed to produce, either directly or indirectly, a photographic image. It is true that none of these subsidiary processes is of value for negative material, since the exposure required with the most sensitive of them is measured in minutes rather than fractions of a second,

but as printing processes they have many interesting applications. Thus, when a solution of gelatine to which a little potassium dichromate has been added is coated on paper and dried in the dark the gelatine can be dissolved off the paper by soaking the sheet in warm water. If, however, the paper is exposed to daylight the gelatine becomes progressively more insoluble as the amount of light falling on it increases. In the original form of this process a water insoluble colouring matter such as lamp-black or carbon was added to the gelatine solution, and exposure was made under a negative through the back of the 'carbon' paper. The exposed paper was then immersed in hot water, when the gelatine which had been rendered insoluble remained on the paper, while the soluble gelatine was washed away. The reason for exposing through the back becomes obvious when we consider what would happen if we exposed through the front surface as in silver printing. The insolubility begins at the surface of the gelatine layer nearest to the exposing light and penetrates deeper and deeper into the film as the light continues to act. In the high-lights of the print, therefore, the insolubility does not extend right through the gelatine layer, but is confined to the surface nearest the printing light, and these high-lights would wash away in the hot water as the soluble gelatine on which they are supported dissolves. By exposing through the paper support, the high-lights and middle tones remain attached to its surface when the soluble gelatine floats away. In modern carbon printing exposure takes place from the front as in normal printing processes and the exposed paper is soaked in cold water and squeegeed into contact with a sheet of celluloid covered with a very thin layer of beeswax. The sandwich is partially dried and then placed in the warm developing water, when the paper backing can be detached and the unwanted gelatine washed away, the pigmented image remaining on the celluloid support. A sheet of water-swollen gelatine coated paper is now squeegeed on to this image and dried *in situ.* As the paper dries it contracts slightly and can be stripped off the waxed celluloid, taking the pigmented gelatine image with it. By this process images can be obtained in a variety of colours, since any water insoluble pigment which will not harden gelatine or be attacked by the dichromate can be incorporated in the original coating. Since gelatine containing dichromate

gradually goes insoluble even in the dark, the commercial carbon papers are coated with gelatine and pigment only, and are sensitized shortly before use by soaking in a dichromate solution and drying in the dark.

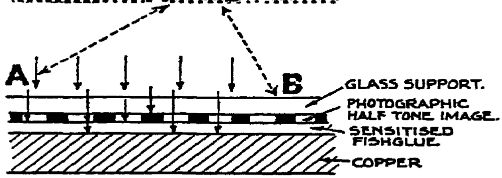
The somewhat complicated and tricky procedure which must be adopted to prevent the partially exposed dichromated gelatine from washing away during development is unnecessary in the most important application of dichromate printing—namely, the production of half-tone printing blocks such as those used to illustrate this book. If one of these illustrations is examined with a magnifying glass the image will be seen to be built up, not of continuous tones of different degrees of blackness, but of solid dots of ink of varying size. In the shadows the dots are large enough to meet, forming an almost continuous black layer, whilst in the high-lights the dots are so small that their presence on the white paper makes a negligible difference to its appearance. In making the blocks from which such illustrations are printed, the continuous tone photographic record is first broken up by optical means into a discontinuous image of the type described. A sheet of zinc or copper is coated with a thin layer of fish glue, which is a kind of gelatine, and alkali dichromate. This layer is now exposed under the half-tone negative until the glue has been rendered insoluble underneath the clear spaces between the dots. The exposure is of such a length that the hardening extends right through the glue film to the metal, and the exposed areas are thus 'keyed' firmly on. Underneath the opaque dots the glue remains soluble, and on treating with water it dissolves away, leaving the metal exposed. There is no need in this process to worry about the retention of the intermediate tones between black and white since there aren't any—the gradation of the negatives being built up, as explained above, of dots of uniform blackness but different size. When the water developed metal plate is placed in a dilute acid solution, the acid attacks the tiny circles of bare metal, hollowing them out into a multitude of tiny pits. The acid cannot penetrate the hardened glue layer, however, so that when this is finally scrubbed away with strong soda, the underlying metal which is to form the printing surface stands up in relief. When a roller charged with printer's ink is passed over the surface of such a plate the roller only makes contact with these raised areas, and so ink is retained by the plate only on these areas, from

1



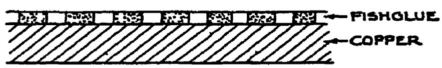
1. The original picture is photographed through a screen, which breaks up the continuous tone image in such a way that the varying tones of the original are converted into opaque dots of varying size. This shows a considerably magnified image of a portion of such a 'half-tone' negative.

2



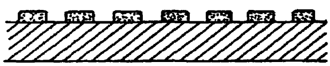
2. Exposure takes place through the half-tone negative, whose opaque image, made up of varying sized dots, prevents light from reaching the sensitised fish-glue coating on the surface of a sheet of copper.

3



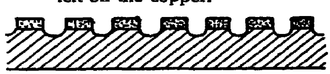
3. After exposure the fish-glue has been rendered insoluble in water wherever light has fallen. These insoluble areas are indicated by stippling.

4



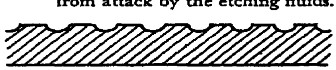
4. When the fish-glue is treated with warm water, a relief image consisting of dots of hardened fish-glue is left on the copper.

5



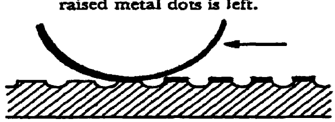
5. The fish-glue image protects the underlying metal from attack by the etching fluids.

6



6. When the fish-glue image is removed an image of raised metal dots is left.

7



7. The inking roller of the printing machine leaves a deposit of ink on the raised metal dots.

8

8. The printer's ink on the raised metal dots is transferred to paper in a printing press giving a half-tone positive reproduction of the original picture.

FIG. 19. SHOWING THE PROCESS OF MAKING A HALF-TONE BLOCK.

which it is then transferred to paper. Thirty years ago a half-tone block of this type took several days to prepare, but nowadays a newspaper photographer can expose a plate in the West End of London and a reproduction of his picture is ready for the printing press within thirty-five minutes of the time when the shutter of his camera clicked.

The dichromates as light-sensitive salts rank second only to silver compounds in the importance and variety of their photographic applications. Thus, not only does dichromated gelatine become insoluble on exposure to light, but it also loses its power to absorb water, and printing processes such as collotype are based on this fact. In collotype a gelatine-dichromate layer is exposed under a negative and then soaked in cold water. The gelatine surface thereupon absorbs water in proportion to the degree of hardening that has been undergone. Since grease and water will not mix, if now a roller charged with greasy ink is passed over the surface of the gelatine, the ink is repelled wherever water is present, and with a proper technique the amount of ink left on the gelatine surface will be inversely proportional to the amount of water held by that surface—that is to say, to the degree of hardening that each area has undergone during exposure. This ink image is then transferred to a sheet of paper squeegeed into contact with the gelatine surface. After the paper bearing the ink image has been peeled away the surface is re-damped, re-inked, and a second image is ready for transference, the process being repeatable many thousands of times.

The acceptance of greasy ink by gelatine hardened or tanned by dichromate salts is the basis of the 'bromoil' process by which many photographers convert bromide prints into greasy ink pictures. Here, however, the dichromate is not the light-sensitive salt, the process consisting in making a bromide print on a special bromide paper whose gelatine coating was not hardened in manufacture. The bromide print is then treated with solutions of which dichromate is an essential constituent, when the silver image bleaches, tanning the gelatine in its immediate neighbourhood. The surface of the bleached print now resembles the collotype plate referred to above, since it bears an invisible image whose varying tones consist of gelatine in varying degrees of receptivity to water. Greasy ink is now applied to the water-swollen print by dabbing

the surface with a brush (bromoil) or a roller (oleobrom), when the ink adheres to the print in proportion to the degree of hardening which has been brought about in each portion of the surface.

Iron Printing Processes. Iron salts form another important class of light-sensitive compounds which have found application as the basis for photographic printing processes. In the case of silver chloride, prolonged exposure to light will break up the compound completely into metallic silver and chlorine, providing, as has already been explained, there is some 'sensitizer' present to absorb the chlorine as fast as it is liberated. In the case of the iron chloride known as ferric chloride, light is only able to remove a portion of the chlorine under similar conditions, and a compound of iron which contains a smaller proportion of chlorine—ferrous chloride—is formed. If, therefore, we sensitize paper with ferric chloride and expose it under a negative the ferrous compound is formed in the exposed areas, and by treating the exposed paper with chemicals which are without effect on ferric salts but which combine with the ferrous salts to form a coloured substance, we can make the effect produced by light visible.

Ferric chloride is not a convenient iron compound to use in practice, and the printing processes based on iron salts usually employ compounds of iron with organic acids such as ferric oxalate, ferric ammonium citrate, &c. For example, by treating an exposed ferric ammonium oxalate paper with a solution of platinum salts, the ferrous compounds produced by light action react with this developer to produce a local deposit of metallic platinum. The 'Platinotype' process is based on this reaction, and although somewhat tricky to work, can be used to produce prints which are more permanent than those obtained by any other paper-printing process, platinum being the most resistant of all metals to attack by chemical agencies. Platinum prints have been recovered with the image quite unimpaired from a sunken ship which has been lying on the bottom of the sea for several years.

Blue Prints. The ferrous image formed by light action on a paper sensitized with ferric compounds will react with potassium ferricyanide to form an insoluble blue compound—prussian blue—and this is the basis of the familiar 'blue-print' process largely used in plan reproduction.

Although it is a waste of time for the amateur to attempt to prepare his own silver printing papers, since his best effort will almost certainly be inferior to any of the commercial brands, this is not the case with the blue-print process. The commercial brands of this paper are intended for the reproduction of line drawings, and in an endeavour to give the whitest possible line on the bluest possible ground commercial papers are deliberately designed to avoid as far as possible the rendering of the intermediate tones. A suitable formula for a blue-print paper to be used for printing from photographic negatives is as follows:

Make a stiff paste of 15 grams (½ oz.) of arrowroot flour and a little water. When the flour is thoroughly wet add water gradually until you have a thin cream. Make this up to 600 c.c. (20 fluid oz.) with hot water, and boil until it is clear. This solution is used to size good-quality writing- or drawing-paper, either by soaking the paper in it for a minute or so, or by rubbing over the surface with a pad of cotton-wool. In either event, remove the surplus sizing solution by drawing the squeezed-out pad in sweeping strokes across the surface until this is as smooth and free from streaks as possible. Dry the paper thoroughly and sensitize it by sponging with a 10 per cent. solution of ferric ammonium oxalate. Apply plenty of the solution, and when the paper is thoroughly covered squeeze out the cotton-wool and remove the surplus solution as before by drawing the pad in sweeping strokes across the surface, preferably in two directions at right angles. The sensitized paper should now be an even pale-yellow colour, and it must be dried in the dark, preferably in a current of air from an electric fan.

Exposure is made to strong daylight underneath a negative until the areas beneath the most transparent portion of the negative are practically colourless. The print is then developed by immersing it in a 10 per cent. solution of potassium ferricyanide. A brilliant blue image appears almost instantaneously, and after half a minute the paper is removed to running water, washed until the yellow stain caused by the developing solution has disappeared from the high-lights, and dried.

Attractive lantern slides or transparencies can be made by fixing out the silver salts from stale plates or films, washing the clear gelatine layer free from hypo, and then immersing it bodily in the above sensitizing solution. After

a minute's soak the plate or film is removed to a warm, dark drying-cupboard and exposed and developed as described.

In normal printing processes light passes straight through the negative to the print. This is not essential, however, and a negative in Australia can be used to make a print in London by converting the light after it has passed through the negative into electric currents, which are transmitted by cable or radio to the receiving station.

The principle upon which the transmission of photographs in this manner depends is the scanning of the surface of the picture with a tiny beam of light. The light passing through or reflected from the transmitting picture falls upon a photo-electric cell which changes the variable intensities of the light beam into proportionate electric currents. In a typical transmitter the picture in the form of a transparency on film is wrapped round a glass cylinder containing the photo-electric cell. The cylinder is rotated while the scanning-beam moves relatively to the picture in much the same manner as the needle moved over the old-fashioned cylindrical phonograph records.

The tiny currents produced in the photo-electric cell are suitably amplified and transmitted by telephone line or radio to the receiving apparatus. Here a beam of light whose intensity is controlled by the received electric currents is focussed on a photographic film or paper mounted on a cylinder in the same manner as at the sending end. Means are taken to ensure that the transmitting and receiving cylinders rotate in exact synchronism, and every portion of the film at the receiving end therefore receives an exposure corresponding to the density of the picture in that region at the transmitting end. To save time, some newspapers make use of apparatus which transmits a negative, printing it as a positive ready for the copyboard at the receiving end. (Plate 23.)

CHAPTER IX

THE RECORDING OF COLOUR

WHEN light enters the eye it arouses two main sensations—one of 'colour' and the other of 'brightness' or 'luminosity'. An ordinary photograph does not record colour as such, and, if it is to appear to be a truthful translation of a coloured scene into monochrome, it must record the light and shade of the scene in the proportionate intensities as seen by the eye, differentiating between the colours by reproducing their luminosity differences. Thus, a photograph of yellow and blue irises should show the yellow petals as a much paler shade of grey than the blue. If, however, we took such a photograph with the silver bromide emulsion whose preparation was described in Chapter V, it would be found that in the print the yellow flowers are almost black, while the blue ones are nearly white. This falsification of luminosity rendering extends to other colours, and to understand how it comes about we must return to a study of the spectrum of white light.

When a beam of sunlight is passed through a prism the various radiations of which it is composed are spread out into a rainbow-coloured band. When we examine this spectrum from the point of view of visual luminosity it is found that the sensation of 'brightness' is at a maximum when looking at the yellow-green region, while the extreme violet and deep red are only seen with difficulty. We can express these observations in the form of a graph in which the visual brightness of any colour in the spectrum is plotted against its wave-length (Fig. 20 A) and a curve showing the relative response of the eye is obtained. If, however, a piece of P.O.P. is placed in the spectrum the greatest darkening does not occur in the visually brightest region, and if we plot extent of blackening against wave-length as before a curve is obtained as shown in Fig. 20 B. A similar result would be obtained by substituting the silver bromide plate we prepared for the white viewing screen on which the spectrum is projected, and, after exposure, developing the plate and plotting the silver density in any region against wave-length. Silver salts are obviously colour-blind in that the band of electro-magnetic rays to which they are naturally

sensitive is for the most part of shorter wave-length than the rays which constitute visible light. It would, indeed, be rather surprising if, out of the tremendous range of such rays, the portion that affects silver salts should coincide with that to which the eye is sensitive, and it is fortunate

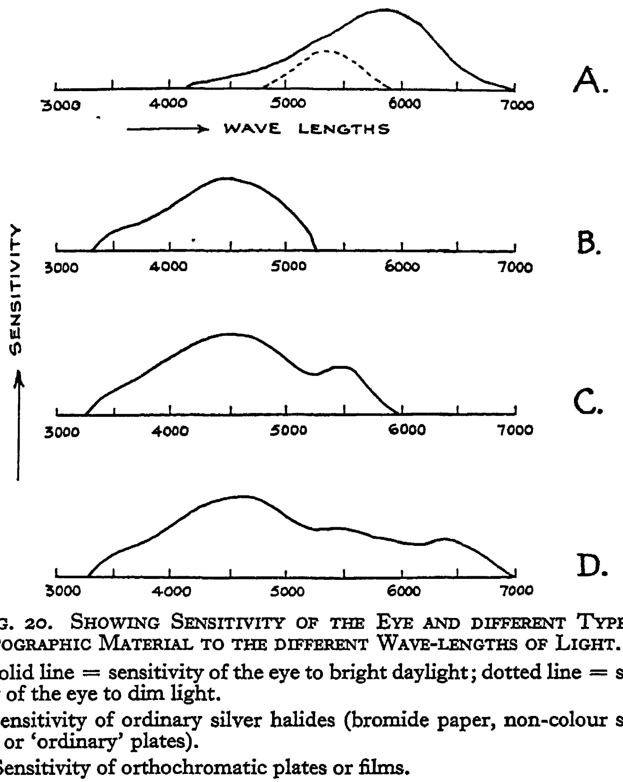


FIG. 20. SHOWING SENSITIVITY OF THE EYE AND DIFFERENT TYPES OF PHOTOGRAPHIC MATERIAL TO THE DIFFERENT WAVE-LENGTHS OF LIGHT.

A. Solid line = sensitivity of the eye to bright daylight; dotted line = sensitivity of the eye to dim light.

B. Sensitivity of ordinary silver halides (bromide paper, non-colour sensitized or 'ordinary' plates).

C. Sensitivity of orthochromatic plates or films.

D. Sensitivity of panchromatic plates or films.

that the two regions overlap on the violet and blue regions of the visible spectrum.

If we place a sheet of orange-red glass in the path of the spectrum it will be found that the violet, blue, and green rays will be stopped by the glass—only the orange, yellow, and red rays passing through to the viewing screen. Moreover, just as the spectrum produced by one prism can be recombined to form white light by passage through a second prism (see page 23), so the yellow, orange, and red rays

which have passed through the orange glass can be recombined to give an orange patch of light, which is the colour of the glass.

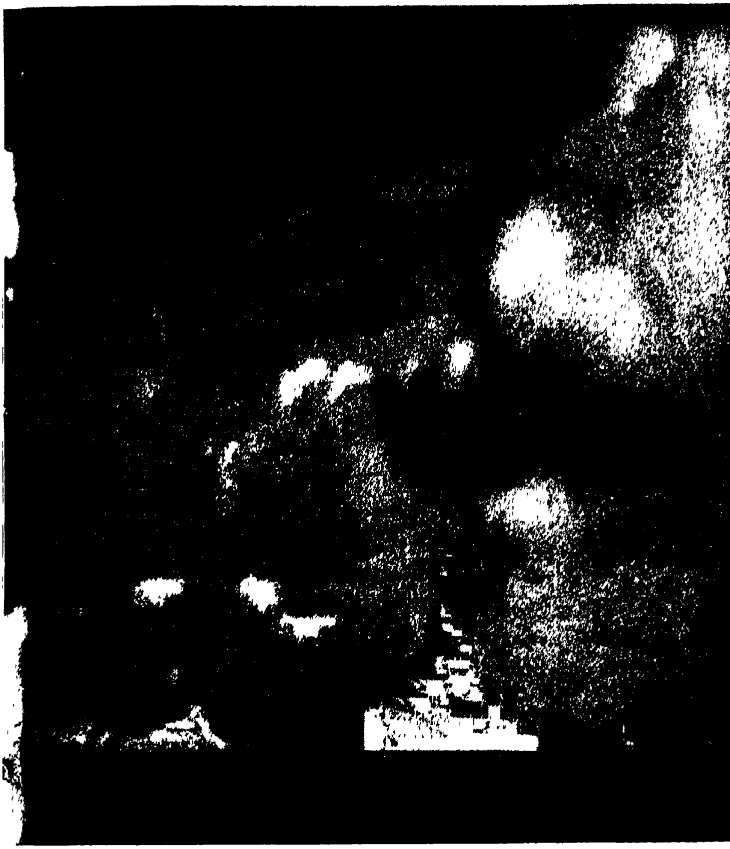
Here, then, is the explanation of why the glass looks orange. It is able to filter out of white light all rays except those giving rise to the sensation of orange. We have seen, however, that these particular rays have no noticeable effect on silver compounds, and accordingly, if before the light from the prism fell on the silver emulsion it was filtered through orange glass there would be no darkening of the paper or developable image formed on the plate because the chemically active rays had been stopped by the orange 'Filter' or 'Screen' as it is sometimes called.

Because of this insensitivity to all colours except blue, it is possible to handle and develop such photographic materials in a room lit with orange light without risk of fogging them. On the other hand, this colour-blindness is a serious drawback when we wish to record coloured objects in monochrome, preserving the visual relationship between the luminosities of the colours.

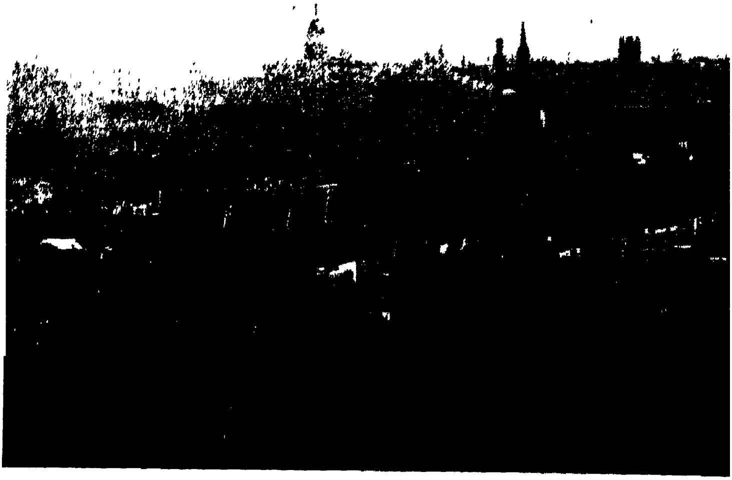
The yellow iris was rendered darker than the blue one because the emulsion is blind to the yellow light which the petals are reflecting, and if we are to obtain a truthful record of the luminosities of colours other than blue, the sensitivity of the silver salts must be extended to the longer wavelengths. This can be accomplished by dyeing the silver grains with certain types of dye-stuff. Thus, our silver bromide emulsion can be made sensitive to green light by bathing it with a dilute solution of the bluish-pink dye-stuff Erythrosine.

That a bluish-pink dye should sensitize the emulsion for green may seem strange until we pause to consider why it is that the dye looks pink. Just as the orange glass looks orange because it absorbs all but the orange-forming rays, so Erythrosine appears bluish-pink to the eye because when white light falls upon it the yellow-green rays are absorbed, and the blues and reds which make up the rest of the spectrum are reflected.

All coloured objects owe their colour to this phenomenon—the selective absorption from white light falling on them of some portion of the rays and the reflection of the remainder to the observer's eye. In the case of Erythrosine, the energy of the absorbed green rays is transmitted to



H.M.S. *Resolution* entering Grand Harbour, Malta *Courtesy of C. Cecil Davies, A.R.P.S.*



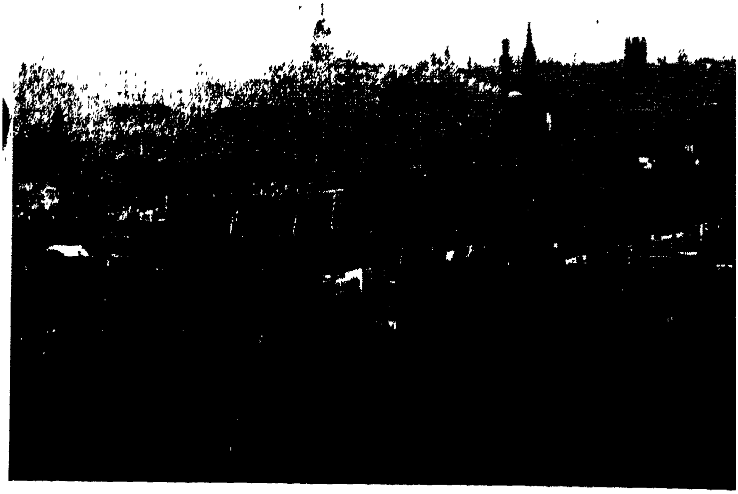
the silver salt, rendering it developable, while the rejected blue and red rays on reaching the eye produce the sensation known as magenta.

A photographic emulsion which has had yellow-green sensitivity conferred upon it in addition to its natural blue-violet sensitivity is called orthochromatic, and the bulk of amateur films are of this type (Fig. 20 C). Such an emulsion, while giving a greatly improved rendering of yellows and greens, is, however, still blind to red. By treating with dye-stuffs known as 'Isocyanines' it is possible to sensitize the silver emulsion for the whole of the visible spectrum. Such emulsions are called 'Panchromatic', and they should preferably be handled in absolute darkness. This is not essential, however, for although the emulsion is sensitive to all colours, the sensitivity is by no means uniform throughout the spectrum, and most panchromatic materials have a comparatively low sensitivity to light belonging to a narrow band in the blue green region of the spectrum.

It so happens that in very poor light the eye is most sensitive to this particular kind of light, and accordingly if the photographer waits for a few minutes while his eyes adapt themselves to dim green light he can 'see what he is doing' though he must not forget that he is then engaged in a race in which the fogging action of the light is matched against his speed of manipulation. When, for some reason, it is necessary to develop by inspection it is convenient to treat the whole plate in darkness with a solution of certain dye-stuffs which largely destroys the light-sensitivity of the emulsion without affecting the developability of the latent image it carries. After a minute in such desensitizing solutions the plate can be removed and developed in comparatively bright light—its sensitivity having been reduced to that of 'gaslight' paper.

For the reasons given in Chapter VII it is not normally necessary to depend either on a green safe-light with its risk of a thin veil of fog, or on desensitizing, since it is comparatively easy so to set out one's dark-room bench that development can be carried out by time and temperature in complete darkness.

The sensitivity of a typical panchromatic emulsion to the spectrum of sunlight is shown in Fig. 20 D, and comparison with Fig. 20 A shows that although sensitive to the whole range of colours, the response of the plate is still very



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different from that of the eye. In particular, the natural blue sensitivity of the plate considerably exceeds the added green, yellow, and red sensitivity, and if we are to translate colour values into luminosities as judged by the eye, it will be necessary to repress the excessive blue sensitivity. The experiment with the orange glass and the spectrum indicates how this can be accomplished. A filter absorbing some of the blue rays must be placed in front of the lens. If we remove some of the blue rays from the spectrum by, for example, placing a piece of card in their path, and then combine the remaining green, yellow, and red rays, the resulting patch will be a bright yellow.[1] It follows that yellow glass owes its colour to the fact that it stops blue rays and transmits the remainder of the spectrum.

In order to make the response of the panchromatic emulsion to the luminosity values of a sunlit subject correspond to that of the eye, exposure is therefore made through a pale-yellow filter of such a depth that it represses the blue rays to the required extent. If a very deep-yellow filter was used the blue would be completely eliminated rather than repressed and the rendering would not therefore be 'natural'. Nevertheless, such deep-coloured filters are of use in technical photography, since they enable the contrasts of colours to be enhanced in the record at the expense of a truthful luminosity rendering.

Suppose, for example, that we were photographing a chess-board made up of yellow and blue squares and that the luminosity of the colours in daylight was such that their brightness to the eye was the same. The eye would easily distinguish the pattern by the colour contrast, though we should be unable to say which colour was the brightest. A panchromatic plate with a pale-yellow correcting filter would record the luminosities as the eye saw them, but could not record the colour contrast. The check pattern would therefore be almost invisible in the photograph, the whole board being rendered as a uniform grey. By using a very deep-yellow or 'contrast' filter the rays of light from the blue squares could be prevented from reaching the emulsion, although the yellow squares would record at full intensity. Accordingly we should then get an excellent

[1] It may at first sight seem surprising that white light minus the blue rays should be yellow, but after all, there is nothing in the sensation of white light itself to suggest that it is actually made up of all the spectral colours!

photograph of the pattern as black and white squares, though the luminosity values on which we depend in an ordinary photograph for a natural impression would be as wrong as they well could be. By using 'contrast' filters strongly repressing different regions of the spectrum it is possible to accentuate any chosen colour—the choice of filter being governed by the simple rule: 'To enhance the contrast between two colours, use a filter which passes one colour freely and absorbs the other.'

During the Great War guns and camps, &c., were camouflaged by painting them with kaleidoscopic colour schemes which a distant observer's eye could not pick out from the surrounding landscape. Contrast filters which ignored the colour scheme and emphasized colour contrasts enabled such camouflage to be revealed by photography.

Such filters have many applications. They are extremely useful in photo-micrography, where it is frequently necessary to differentiate as markedly as possible between differently stained portions. They enable the grain of polished furniture to be brought out to any desired extent.

In black and white photography, therefore, use is made of two different types of filter: correcting filters, which are usually pale yellow, are used to cut out the ultra-violet and repress the blue, so that the emulsion responds to the brightness of the subject in a manner which is similar to the eye; and contrast filters, whose colour varies with the colour it is desired to emphasize.

Recently sensitizers have been found that increase the red sensitivity of the emulsion to so great an extent that, unless this end of the spectrum is also repressed, the rendering of photographs taken in daylight will not be absolutely truthful, and these 'hypersensitive panchromatic' emulsions are therefore used with a pale-green filter, which represses both the excessive blue and red sensitivity.

When a blue-sensitive emulsion is green sensitized its effective working speed increases, for it now records the green light to which it was previously blind, whilst the panchromatic emulsion, being sensitive to all the light reflected from the subject, will be of even higher speed.

When a correcting filter is used in conjunction with such colour-sensitized emulsions it is obvious that the effective speed will be lowered, since the filter is cutting out some of the actinic rays. The number of times that exposure must

be increased when photographing through a filter in order to counteract this loss is termed the 'filter factor'. Thus, if the correct exposure with no filter is one-quarter of a second, the exposure through a filter of factor 2 will be half a second, and so on. Whether the improved rendering obtained by the use of the correcting filter appropriate to any particular manufacturer's emulsion is worth any disadvantage the extra exposure may involve is obviously a matter for individual judgement.

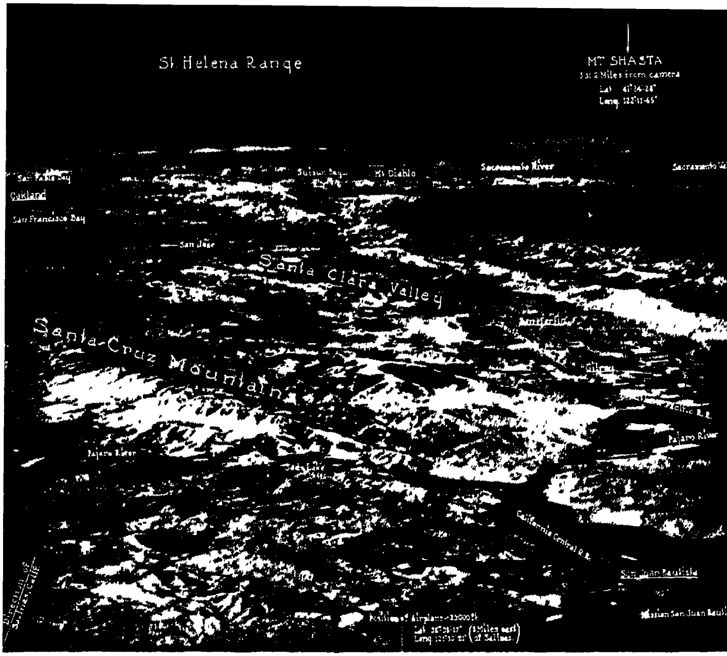
For ordinary holiday snapshot photography an unfiltered orthochromatic emulsion is almost universally employed, whilst an unfiltered panchromatic emulsion gives a very good representation of the original colours of natural landscapes, which consist for the most part of greys slightly tinted with colour.

Nevertheless, even the amateur who cares little for the increased truthfulness of properly filtered panchromatic material will find a yellow filter necessary if he wishes to record clouds in his sunlit landscape pictures, and for mountain scenery where the blue and ultra-violet rays are particularly prevalent such a filter should be considered as essential. The yellow filter assists the cloud rendering by holding back the exposure due to the blue sky, and so permits this to appear in the print as darker than the clouds, which corresponds to the visual impression. (Plate 24.)

COLOUR PHOTOGRAPHY

Colour photography has been possible since the beginning of the present century, but it is only within the last few years that processes have been brought to a point where the production of colour photographs is possible to other than enthusiastic experts. Recent improvements in apparatus, photographic materials, and technique, and extensive research have simplified the photographer's task to so considerable an extent that it is now possible for any one capable of making good black-and-white photographs to record the colour as well as the form of nature.

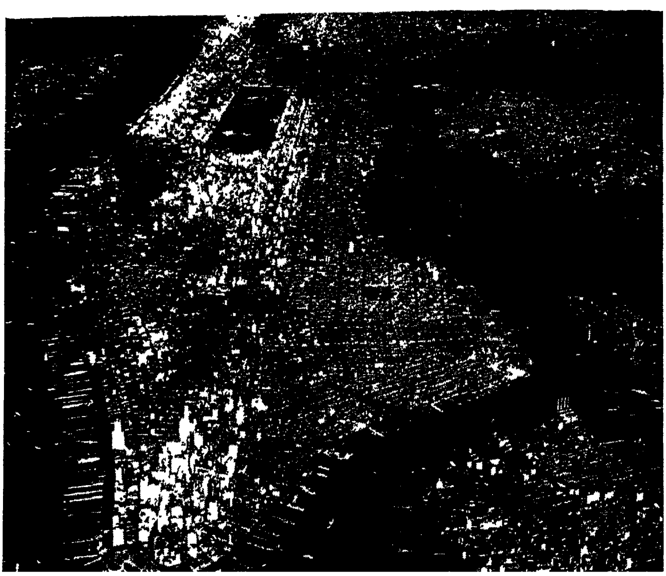
If we are to understand the basis of the available systems we must bear in mind the reason why things look coloured. If white light falls upon any object the object will appear white only if its surface is capable of reflecting back all the light falling upon it. On the other hand, it will appear black if its surface is capable of absorbing all the light, reflecting



The longest distance yet photographed : Mount Shasta, 331·2 miles from the camera

Courtesy Capt. A. W. Steve

An infra-red photograph taken from an aeroplane at a height of 21,000 feet, showing practically the whole of the county of London, a large part of Essex, and most of the coast-line of that county. November 1934 *Courtesy of The Times*



none back to the eye. We have already noted, however, that white light actually consists of a mixture of light of different colours, and that a piece of red paper, for example, looks red because the pigment with which it is coloured removes or subtracts from white light falling upon it all the colours of the spectrum except the reds, and these it reflects to the eye.

We can, of course, make a piece of white paper look red by taking it into a dark-room and shining a red light on it. Here the subtraction of the other colours of the spectrum takes place as the white light passes through the coloured glass in front of it.

Suppose now that whilst the red light is shining on the paper we also shine a green light on it from another lantern. Then the white paper will reflect back to us a mixture of green and red light and it will look yellow. Many people find it difficult to believe that this is the case—that we can produce yellow by mixing red and green light—but it is quite easy to prove it by painting one end of a pack of cards bright red and the other end bright green. On reversing every other card and viewing the end of the pack from a distance of several feet it will look yellow, although actually built up of alternate red and green edges.

If we divide the spectrum of white light into three equal parts and collect all the rays in each section together the result is orange-red, yellow-green, and blue-violet light.

We have already seen that red and green will give yellow. All three lights together will, of course, give white, since each represents one-third of the spectrum, and Clark Maxwell found that every colour in Nature could be matched by mixing appropriate proportions of these three coloured lights—the so-called primaries.

Colour photography is based on this discovery, since it consists in photographing separately the redness, greenness, and blueness of the subject and then by some means recombining the primary records.

If we place a red filter in front of a camera lens and allow the transmitted image to fall on a panchromatic plate the filter will only allow those rays of light in the red region of the spectrum to fall upon the plate, and accordingly when we develop our negative the silver deposit obtained is due solely to the red rays reflected from the object on which the camera is focussed, and the density of the deposit at any portion is determined solely by the amount of red reflected

to that point from the subject. We have, in fact, translated red light intensity into equivalent opacity.

In the same manner, negatives which are a record of the green rays and blue-violet rays are obtainable through green and blue-violet filters each of which transmits about one-third of the spectrum.

Now let us consider the nature of a positive transparency print from the negative made through the red filter. For the sake of simplicity, we will assume we have photographed a red circle on a green-and-black background. In the negative, wherever red light fell on the plate a deposit of silver was obtained, and therefore in the positive this portion of the plate will be more or less transparent. On the other hand, the green rays reflected from the green background, being absorbed by the red filter (which it will be remembered absorbs all but the red rays) will be without effect on the negative and the latter will be free from silver deposit in the regions corresponding to this background. No light reaches the plate from the black areas since none is reflected from it. As a result the positive transparency print from this negative will be opaque in these regions. If, therefore, by means of a lantern we project a beam of red light through this transparency on to a screen we shall obtain on the screen a red picture which is a record of the red rays reflected from the original object. Wherever there was no red in the original subject there will be no red on the screen—only black. The same argument applies to transparencies from the green and blue filter negatives projected through the green and blue-violet filters.

Now suppose that, using three lanterns, we project these three coloured images on top of each other in register. Then since every colour can be matched by mixing appropriate proportions of our three primary colours, and since this proportioning has been accomplished by our original silver deposits, a picture in correct colours is obtained. In Fig. 21 these steps are shown in diagrammatic form. For the sake of simplicity only the making of the red and green records are illustrated, since these two are sufficient for the reproduction in colour of the simple subject chosen. When photographing a more elaborate colour scheme a blue filter record, made in precisely similar manner, will, as explained, also be necessary. Since the coloured result is obtained by adding together appropriate proportions of the primary

lights, this method is known as 'additive' colour photography; and to reduce the system to a practical form, which has made its popularization possible, the three separate

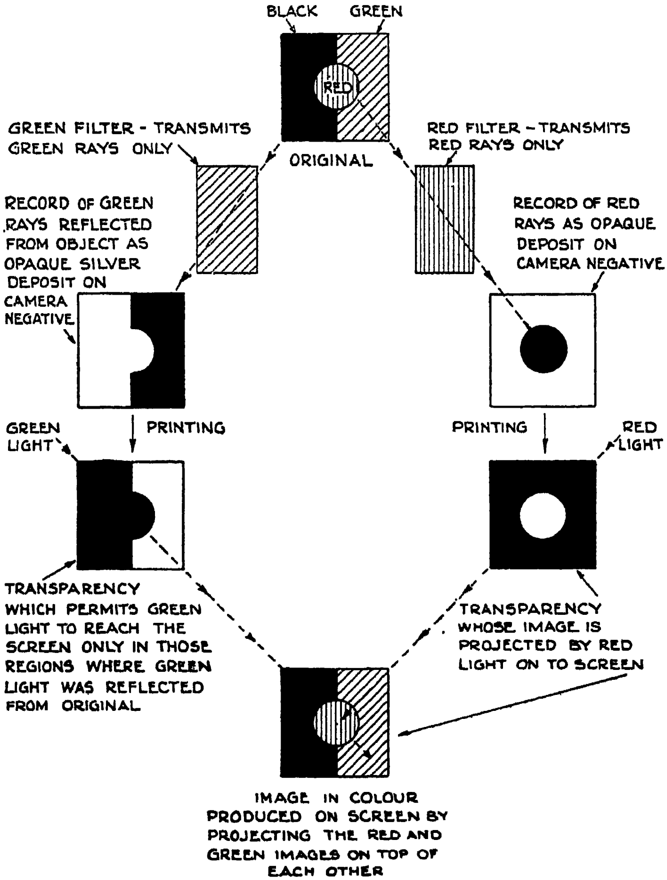


FIG. 21

images are obtained all on the same plate and at one exposure by covering the surface of the emulsion nearest the lens with colour-filter elements of microscopic size intermingled in close juxtaposition—the so-called Mosaic Screen processes. The 'Autochrome' is typical of such plates. Three equal portions of potato starch grains are dyed respectively red, green, and blue-violet. The dyed grains are then mixed

together and the mixture dusted on to a glass plate covered with a tacky coating. The surplus grains are shaken off, and those adhering to the glass are flattened out under great pressure, producing a mosaic of microscopic colour filters. Upon this mosaic a panchromatic emulsion is coated, and the resulting plate exposed in the camera with the mosaic nearest to the lens.

If a photograph of a red object is taken upon such a plate, the red rays from the object pass unhindered through the tiny red elements of the mosaic and affect the emulsion, with the result that after development there is an opaque silver deposit exactly underneath each red element. The red rays are, however, absorbed by the green and blue elements, and the emulsion under these elements is therefore unaffected. The developed plate is now placed in a solution which dissolves out the developed silver image but leaves the unexposed emulsion unaffected. After leaving the bath, therefore, the plate is transparent under the red elements. The unaffected emulsion under the green and blue elements is now blackened by a second development, and in consequence, when the plate is viewed by transmitted light, the latter is only able to pass through the red filter elements. (See Fig. 38, page 135.) In the case quoted we have considered the reproduction of a red which is spectrally simpler than the red of the colour mosaic. The majority of colours are, of course, more complex than this, and varying proportions of the constituent rays will pass through all three elements, producing varying degrees of opacity behind these elements which, after the reversal process, become varying degrees of transparency allowing appropriate proportions of each of the three colours to pass. These are blended on the screen or confused together by the eye to reproduce the original colour.

All mosaic screen processes are based upon the same general principles, differing from each other chiefly in the methods by which the mosaic is produced. Thus the Dufaycolor mosaic is a geometrical pattern of printed red lines and blue and green squares on a film support (Fig. 22). The film base is first coated with a layer of collodion coloured primary blue. An engraved cylinder prints a pattern of fine lines in greasy ink on this coloured layer—the lines being so small that forty together are only 1 millimetre wide. The printed film is then passed through a bleaching bath, where the dye

not protected by the grease is removed, into a bath of green dye. The bleaching bath and green dye can only penetrate the interspaces between the ink lines, and accordingly, when the greasy ink lines are removed by passing the film through a bath of benzene, a pattern of blue and green lines is revealed. A second set of ink lines is now printed on the film at an angle to the first set, and the unprotected interspaces are bleached and dyed red. The ink is removed, and a geometrical mosaic of blue and green squares separated by red lines — roughly one million colour elements to the square inch—is obtained. A panchromatic emulsion is coated on this mosaic, and the film is exposed and processed in a similar manner to the autochrome.

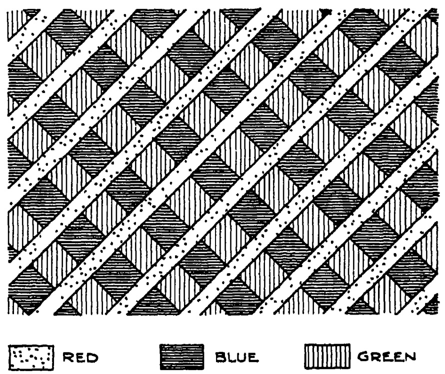


FIG. 22. DUFAYCOLOR MOSAIC.

The Finlay process differs from the above in that the colour mosaic and the photographic emulsion are carried upon two separate glass plates which are exposed in contact face to face. After the negative has been developed any number of colour positives can be made from it by the normal methods of lantern-slide making, and these are then bound up in register with a geometrically identical mosaic for viewing.

The manipulation of these additive screen plates presents no great difficulty to any photographer, and when transparencies (lantern slides, &c.) are required the additive processes provide the simplest means of obtaining these.

Unfortunately these additive processes in practice are limited to such transparencies, since, if an additive screen plate picture is laid down on a sheet of white paper, the result is so dark as to be practically useless.

In the additive processes the brightest portions of the picture—the whites—are made up by adding together the three primary lights, red, green, and blue. Each of the filter elements is acting by absorbing at least two-thirds of

the incident white light, and therefore at least two-thirds of the white light passing through the filter elements on its way to the paper base will be absorbed and cannot reach the eye, so that even the whites of our additive picture will send to the eye, under ideal conditions, not more than one-third of the light which the paper base itself is reflecting. Moreover, white paper itself appears white not because it reflects all the light that falls on to it, but because it does not exercise a selective absorption upon this light, but reflects every ray in a similar proportion. As a matter of fact, approximately 20 per cent. of the rays falling on white paper are absorbed, and in consequence by the time, for example, the red rays from our red filter element have reached the eye, the light loss is so considerable that the colour appears to be very dark red indeed. It is not therefore practical to view an additive screen plate image by backing it with white paper, although a somewhat dull picture *is* seen if a more effectively reflecting backing such as silver foil is used.

Subtractive Processes. How are we to overcome this defect and obtain colour photographs on paper of sufficient luminosity to be of practical use? Let us return for a moment to the originally described colour process in which transparencies from our negatives were projected in register through the taking filters. It will be remembered that these taking filters were defined by the fact that they transmitted one-third of the visible spectrum and absorbed the remaining two-thirds. In our positive transparency, therefore, the clear glass areas are those through which one-third of the spectrum —the red, say—is to pass, and we colour these areas red by our filter. It follows, therefore, that the duty of the opaque areas on this transparency is to control the amount of red light that reaches the screen in any particular area. The presence of the silver deposit in the transparency means, therefore, either that there was little red in this portion of the subject, or that the colour of this portion was not red at all. Notice, however, that the silver deposit must not prevent the rest of the spectrum from reaching the screen, or no colour picture could result, and in the case under consideration it has no opportunity of doing this because these other coloured rays are coming from separate light sources.

But for our print on paper we can use only one light source—namely, that falling on the paper and reflected

back to the eye. We must therefore turn our black silver deposit into one which, whilst absorbing all the unwanted red rays from the incident light, will yet allow all the rest of the spectrum to pass unhindered. This is accomplished by turning our opaque silver image into a transparent blue-green—that is, turning it into a colour filter which transmits every portion of the spectrum except red.

We start with white light, represented by a sheet of white paper, and subtract from it the unwanted radiations. The printing colours used in three-colour work are therefore white light minus primary red, i.e. blue-green; white light minus primary green, i.e. pink; and white light minus primary blue, i.e. yellow. This conception is easier to grasp when it is remembered that when we take an ordinary monochrome photograph by white light we make the print with a pigment which represents absence of white light, namely black, or, using the same terminology as above, in a 'minus white' pigment.

An analogy may be drawn between additive and subtractive colour photography and modelling and sculpture. The modeller starts with an empty pedestal and adds clay to it in appropriate shapes until his model is complete, whereas the sculptor is a 'subtractive' worker, for he starts with a block of marble and chips away unwanted material until the figure is complete. In just the same way, in additive colour photography we start with a dark screen and build up the picture by adding to it coloured light, whereas in the subtractive processes we start off with white light represented by a sheet of white paper and subtract from this all the colours that are not actually required.

The three subtractive primary colours, yellow, pink, and blue-green, are, of course, the artists' 'primaries' with which most people who own a paint-box are familiar.

When we have toned our three transparencies to the transparent colour complementary to each taking filter it will be found that they can be superimposed in register on a white surface and that a satisfactory colour print is obtained. The whites of our print are now areas in which there is no colour deposit at all, and they are therefore as bright as the paper support. Moreover, since by definition the toning colours we have used are those which absorb from white light the unwanted rays and transmit the rest, the colour range is obtained by such absorption. Thus, a

primary red in a subtractive colour print is obtained by superposing a yellow image (which absorbs blue) and a bluish-pink image (absorbing green). Since the yellow removes the blue and the bluish-pink removes the green, only the red rays of the spectrum will be reflected back to the eye. (Fig. 23.)

The way in which the various colours are obtained in a subtractive print will be made clear by studying the following diagram which represents a section through a colour

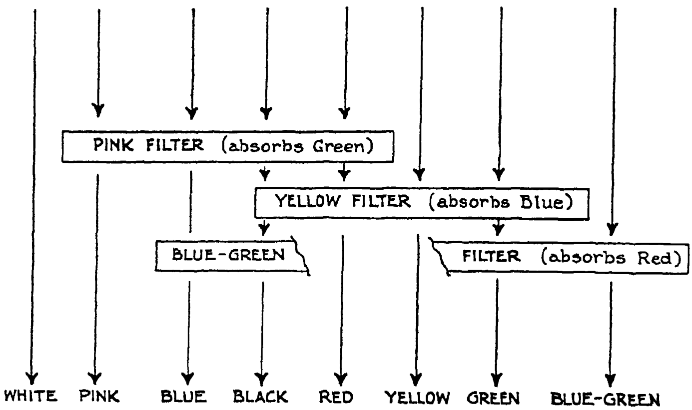


FIG. 23.

chart made up by superposing pieces of pink, yellow, and blue-green gelatine.

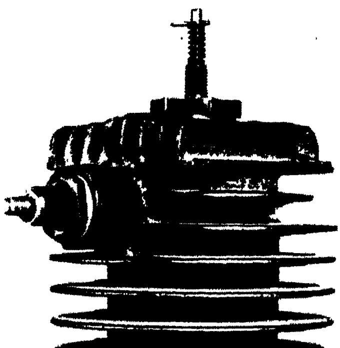
All subtractive processes require three negatives of the subject exposed either simultaneously or in rapid succession through the three primary colour filters. The simplest method of obtaining these is to use an ordinary camera and expose the three plates in succession, but this method is, of course, only possible with still-life subjects owing to the length of time required for the various operations. Devices for changing the plates automatically are now marketed which reduce the period required for all three exposures to under 2 seconds, and the majority of natural colour portraits made by professional photographers in England are photographed with automatic cameras of this type.

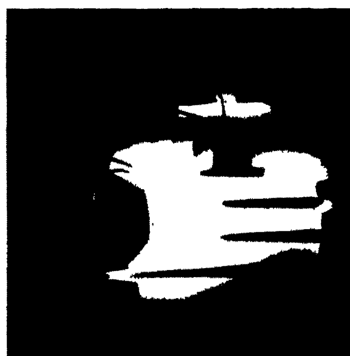
For snapshot work many types of cameras have been devised in which all three plates are exposed simultaneously, light from the lens being divided up inside the camera by

Portrait of a bust made in the darkness, using two electric flat-irons as sources of heat radiation. Exposure 1 hour, f/4.5

Normal photograph of the set-up

Courtesy of Kodak Research Laborator





Left: normal photograph of Internal Combustion Engine; *right*: the same engine photographed by its own heat

Courtesy of Ilford Lt

Cinema audience photographed during performance by invisible infra-red radiation

Daily Mail Photograph
Courtesy of Ilford Ltd.

an arrangement of prisms or mirrors which divert appropriate fractions of the light to the three plates. Fig. 24 shows a skeleton view of such a camera, the path of the light rays being indicated by arrows.

With such apparatus the making of the necessary negatives is a relatively simple task, but the production of a satisfactory print from them is a very different matter. Many possible methods have been devised involving dye-

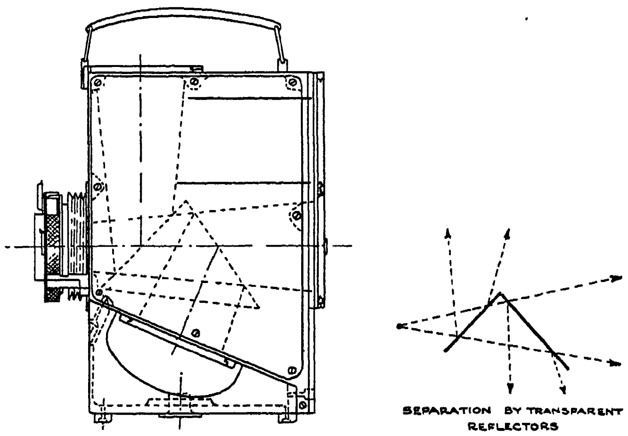


FIG. 24.

toning silver positives, making coloured gelatine relief images or causing films of dye to transfer from stained silver positives on to a sheet of gelatine-coated paper. It is beyond the scope of this book to enter into details of such methods, and interested readers are referred to the bibliography (page 159).

Although it is a relatively simple matter to make excellent colour transparencies by the additive mosaic screen processes, very few people possess the skill and patience for making successful subtractive colour prints, and the process did not obtain any real popularity until a few years ago, when a factory was established in London for producing such prints from negatives made by photographers.

In this factory every operation in the making of a colour photograph is standardized, and owing to the scale on which the process is worked, it is possible to employ elaborate and expensive methods of controlling the variable factors that

make subtractive printing processes so tantalizingly uncertain in the hands of the solo worker.

We can summarize this outline of the basis of colour photography as follows:

(1) Light is a wave phenomenon, and the wave-length of any particular ray determines its colour. White light is a mixture of all the radiations occurring in the visible spectrum.

(2) If we divide the spectrum into approximately equal thirds and collect all the rays in each section together, the result is orange-red, yellow-green, and blue-violet light.

(3) Every colour occurring in Nature can be approximately matched by mixing together appropriate proportions of these three primary lights.

(4) In 'additive' processes of colour photography the coloured result is obtained in this manner—we superpose (projection lanterns) or add together (tiny filter elements side by side) appropriate portions of the three coloured lights each consisting of one-third of the spectrum.

(5) In Nature substances are not coloured in this way, but instead they absorb or subtract certain portions of the visible spectrum of white light and reflect the remainder. It is this composite reflected portion which is the colour the eye records as the natural colour of the object, and this phenomenon is the basis of the 'subtractive' colour processes.

From the point of view of the amateur, the additive processes have the merit of simplicity. Providing he is reasonably careful to give the right exposure (necessarily longer than a black-and-white under equivalent conditions, since only one-third of the light entering the camera reaches the emulsion, the remainder being absorbed by the filters), he can produce excellent transparencies by following a straightforward technique.

The subtractive process is of greater use to the professional photographer, but the various stages in the production of a subtractive print are so tricky and complicated that only enthusiasts attempt the making of subtractive prints, and professional photographers usually send their exposed negatives to factories specially equipped for the purpose of printing from them.

CHAPTER X

PHOTOGRAPHY BY INVISIBLE 'LIGHT'

ALTHOUGH the eye is only sensitive to a small fraction of the tremendous range of electro-magnetic rays, it was pointed out in Chapter II that other radiations can be grouped together and broadly classified by their distinctive properties. These different properties merge gradually into one another as we move up and down the range, and in the case of the group of rays whose distinctive characteristic is that they constitute visible 'light', the actual visibility is at a maximum in the yellow-green region.

As we pass down the spectrum from this point the visible effect gets smaller until, after 7,500, which is just discernible as a dark crimson red, we come to the invisible 'infra-red' rays, which merge imperceptibly into heat rays. In the other direction the visible rays just beyond the violet—the ultra-violet—are sometimes called the 'actinic' rays on account of their chemical activity.

In Chapter IX it was explained that an ordinary silver bromide emulsion has maximum sensitivity to the blue and ultra-violet rays, but that if certain dye-stuffs were added to photographic emulsions the latter became sensitive to the colours which the dye-stuff absorbed. By suitable combinations of such dye-stuffs photographic plates are now made which, in addition to their inherent blue and violet sensitivity, will record green light (ortho), green-yellow, and red (panchromatic). Panchromatic emulsion is thus sensitive to all the rays which we recognize as visible light.

Discoveries did not stop at this point, however, and dyes were found which sensitized the emulsion for the infra-red, i.e. for rays which, being of longer wave-length than the visible spectrum, were invisible to the human eye. Some idea of the way in which the photographable spectrum has been extended since this form of sensitization was discovered is given by Fig. 25, and the ability to record on a photographic plate the effect of these invisible radiations is becoming of increasing importance to science, industry, and human welfare.

Infra-red Photography. Photography by means of infra-red radiations is of particular interest to the amateur,

not only on account of its many fascinating applications, but because, unlike photography by other invisible radiations, he can undertake it himself. The only additional equipment required is a special light filter and a supply of infra-red plates or films, which are obtainable from dealers at little more than the price of ordinary material. The filter itself is practically opaque—its function being to absorb all

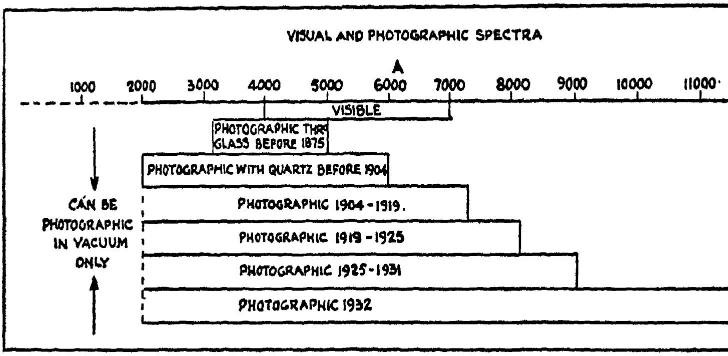


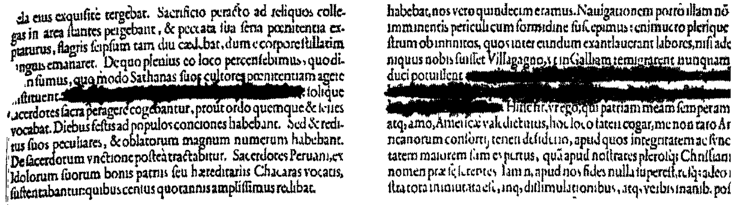
FIG. 25.

the visible light to which the photographic plate is normally sensitive and allow only the infra-red rays to reach the emulsions, and with the material available slow snapshot exposures are possible. Plate 25 shows a typical result obtained when a landscape is photographed by the infra-red rather than the visible light rays. The two most striking things about such pictures are the impression that the green foliage gives of being covered with snow, and the distance, which is usually hazy in a photograph, is surprisingly clear.

The unnaturally light rendering of the green leaves and grass is due to the fact that their green colouring matter (chlorophyll) does not absorb infra-red rays as strongly as it does the visible and actinic rays. Accordingly, a greater proportion of infra-red radiation than visible light is reflected from the foliage to the plate, the silver deposit in the negative is therefore greater, and the final print correspondingly lighter wherever foliage is recorded.[1]

The clear rendering of distant objects is due to the greater ease with which rays of long wave-lengths penetrate a hazy

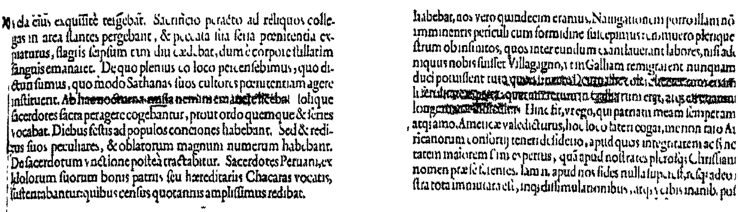
[1] A possible alternative explanation is that chlorophyll converts rays of shorter wave-length into infra-red rays by fluorescence (see page 115).



da eius exquisitè tergebat. Sacrificio peracto ad reliquos colle-
gas in area stantes pergebant, & peccata sua sera pœnitentia ex-
piaturus, flagris seipsum tam diu cædebat, dum e corpore stillatim
sanguis emanaret. De quo plenius eo loco percensebimus, quo di-
cturi sumus, quo modo Sathanas suos cultores pœnitentiam agere
instituerit. [redacted] Iolique
sacerdotes sacra peragere cogebantur, prout ordo quemque & series
vocabat. Diebus festis ad populos conciones habebant. Sed & redi-
tus suos peculiares, & oblatorum magnum numerum habebant.
De sacerdotum unctione posteà tractabitur. Sacerdotes Peruani, ex
Idolorum suorum bonis patriis seu hæreditariis Chacaras vocatis,
sustentabantur: quibus census quotannis amplissimus redibat.

habebat, nos vero quindecim eramus. Navigationem porrò illam nō
imminentis periculi cum formidine suscepimus: enimvero plerique
strum ob infinitos, quos inter eundum exantlaverant labores, nisi ad-
niquus nobis fuisset Villagagno, ut in Galliam remigrarent nunquam
duci potuissent [redacted] Hinc fit, ut ego, qui patriam meam semperam
atq; amo, Americæ valedicturus, hoc loco fateri cogar, me non raro Am
ricanorum consortij teneri desiderio, apud quos integritatem ac sinc
tatem maiorem sim expertus, quā apud nostrates plerosq; Christiani
nomen præ se ferentes. Iam n. apud nos fides nulla superest, resq; adeo
stra tota immutata est, inq; dissimulationibus, atq; verbis inanib. pos

Illustrating of deleted passages.



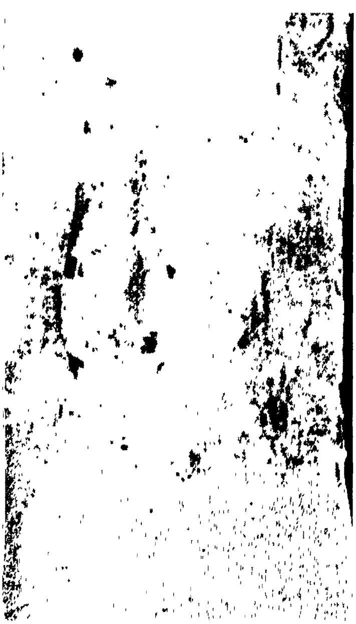
da eius exquisitè tergebat. Sacrificio peracto ad reliquos colle-
gas in area stantes pergebant, & peccata sua sera pœnitentia ex-
piaturus, flagris seipsum tam diu cædebat, dum e corpore stillatim
sanguis emanaret. De quo plenius eo loco percensebimus, quo di-
cturi sumus, quo modo Sathanas suos cultores pœnitentiam agere
instituerit. Ab [illegible] Iolique
sacerdotes sacra peragere cogebantur, prout ordo quemque & series
vocabat. Diebus festis ad populos conciones habebant. Sed & redi-
tus suos peculiares, & oblatorum magnum numerum habebant.
De sacerdotum unctione posteà tractabitur. Sacerdotes Peruani, ex
Idolorum suorum bonis patriis seu hæreditariis Chacaras vocatis,
sustentabantur: quibus census quotannis amplissimus redibat.

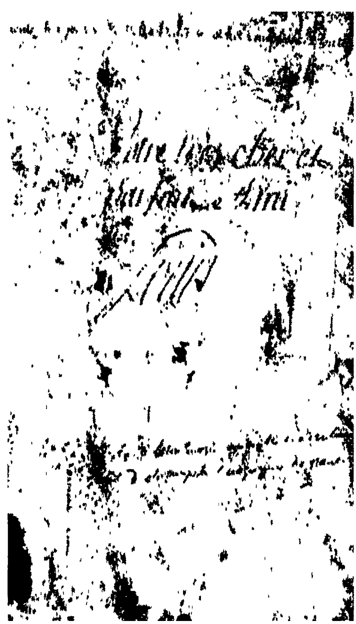
habebat, nos vero quindecim eramus. Navigationem porrò illam nō
imminentis periculi cum formidine suscepimus: enimvero plerique
strum ob infinitos, quos inter eundum exantlaverant labores, nisi ad-
niquus nobis fuisset Villagagno, ut in Galliam remigrarent nunquam
duci potuissent [illegible]
[illegible]
longe [illegible] Hinc fit, ut ego, qui patriam meam semperam
atq; amo, Americæ valedicturus, hoc loco fateri cogar, me non raro Am
ricanorum consortij teneri desiderio, apud quos integritatem ac sinc
tatem maiorem sim expertus, quā apud nostrates plerosq; Christiani
nomen præ se ferentes. Iam n. apud nos fides nulla superest, resq; adeo
stra tota immutata est, inq; dissimulationibus, atq; verbis inanib. pos

Infra-red photograph of the same.

Deciphering documents by infra-red photography

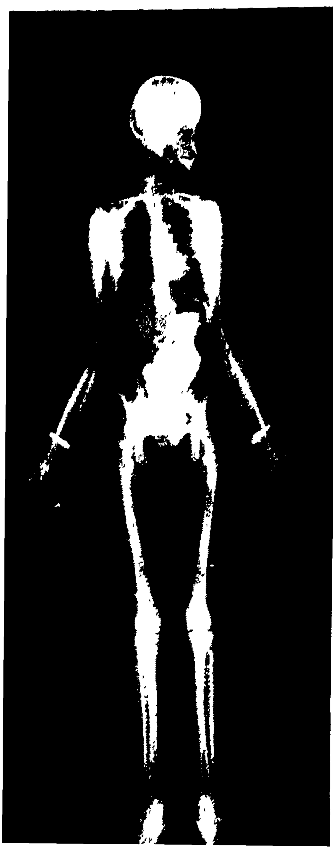
Courtesy of Dr. L. Bendikson, Huntington Library, San Marino, C





String flashover on insulators ($\frac{1}{2}$ million volts)

Courtesy of G. G. Hoare, A.R.P.S.



atmosphere. The water particles suspended in the air scatter the short blue and violet rays by reflection more readily than they do the longer orange and red rays, and if any considerable proportion of the rays of light proceeding from the distant object to the camera lens are scattered by reflection it is obvious that a clearly defined image cannot be formed by them. Incidentally, that is why in foggy weather some motorists put an orange filter over their headlights. They hope, by cutting out the blue, easily reflected rays, to lessen the confusing 'glare' due to scatter. Actually it is doubtful whether these filters are generally sufficiently red to make any appreciable difference to the motorist's distance of clear vision—they are merely a step in the right direction.

Infra-red radiation, however, is scattered very much less than visible red light, and when we use infra-red sensitive photographic material it is possible to obtain clearly defined distance photographs in hazy weather, and even to photograph subjects which are invisible to the eye because they are lost in the prevailing haze or mist. Plates 26 and 27 are typical of such photographs.

The ability of infra-red radiation to penetrate fog has been grossly overrated by the sensational press, and very long distance photographs such as those shown require an exceptionally clear atmosphere. So far it has been demonstrated that the camera can 'see' farther than the human eye through mist or heat haze, but how much farther under varying types of atmospheric conditions the scientists who work on this problem are less ready to commit themselves than the newspaper reporter who wants an attractive story!

However, even although the infra-red emulsion is nearly as blind in a real fog as the human eye, its keener vision is finding increasing application in science and industry. Thus, one of the remaining difficulties in photographing the distant nebulae is this problem of scatter, and infra-red sensitive plates are now used extensively by astronomers. They have by this means been able to record individual stars in nebulae which appear on ordinary plates as a mere blur of light, and infra-red photographs of the surface of Mars have revealed many details which are not recorded on ordinary plates.

Infra-red radiation is nearer akin to heat than to visible light. If, for example, it is allowed to fall on a delicate

thermometer, a rise of temperature is recorded. If a current of electricity is passed through a lamp or radiator the wires become heated, the temperature which it attains depending upon the amount of the current and the resistance of the wire. As the current increases the wire first becomes warm, then too hot to hold, then red hot, and finally white hot. In other words, as the temperature rises the rays emitted become of shorter and shorter wave-length and are finally visible as light. The interesting point is, however, that when the wire is too hot to touch but yet not hot enough to be emitting visible light, it is nevertheless radiating the invisible infra-red rays by which photographs in absolute darkness can be taken. One of the subjects on Plate 28 is such a photograph, showing one of the applications of this type of photography. It is the cylinder head of a motor-car engine photographed by the 'light' of the infra-red rays it emits when it is hot. The photograph clearly shows the heat gradient in the various parts of the casing, and by measuring the photographic densities the heat distribution in the iron can be determined. Such photographs require several hours' exposure, but snapshot exposures are obtainable by using special infra-red filters, opaque to visible light, in front of powerful electric lamps. With these specially filtered lights kinema audiences have been photographed without being aware that they were 'illuminated' for this purpose, and recently an infra-red kine-film taken in absolute darkness was shown in London. (Plate 29.)

When such portraits are closely examined it is found that clean-shaven men appear to be unshaven—the infra-red rays penetrate just beneath the surface of the skin and so reveal the outlines of to-morrow's shave! Varicose veins which are not visible to the eye are also recorded in such photographs.[1]

Three hundred years ago the Inquisition censor obliterated with black ink part of the text of a manuscript of which

[1] This ability of infra-red radiation to penetrate matter normally considered opaque must be borne in mind by the photographer when choosing the camera he will use. An all-metal camera is perfectly safe, but flimsy leather bellows and vulcanite dark-slides may both result in fogged plates. Moreover, when working at full aperture where the depth of focus is small, the infra-red rays do not come to quite the same focus as visible light (see page 24), and it is necessary either to rack the camera lens very slightly forward after focussing, to use a specially corrected lens in which the infra-red and visible rays come to the same focus, or to stop down a f4·5 lens to f11 and so increase sufficiently its depth of focus.

he did not approve. Unfortunately for his wishes, the ink he used to cover the offending passages has also proved transparent to the infra-red rays, as Plate 30 clearly shows.

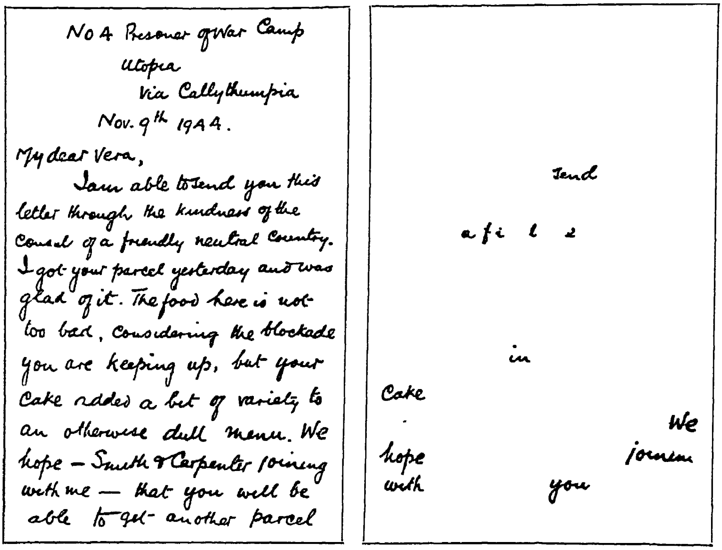
Although infra-red is finding increasing application in the examination of such documents, the usual procedure in dealing with erasures, blacking out, alterations, and supposed forgeries is to photograph the suspected document in ultra-violet light. Here the value of the method depends not so much on the penetrability of the ultra-violet, but upon its power of producing a characteristic 'fluorescence' in different materials.

Fluorescent substances have the power of absorbing light of very short wave-length, and somehow converting it into light of longer wave-length. Familiar examples of such substances are quinine and red ink. In these two cases the ultra-violet radiation is converted into visible light rays of longer wave-length—the peculiar blue sheen seen in quinine solutions and the green sheen seen in red ink being due to fluorescence caused by the ultra-violet present in daylight, and the sheen disappears in electric light whose ultra-violet content is negligible. With some substances, however, fluorescence is not visible because, although the transformation from short to longer wave-length has occurred, the longer wave-lengths are still too short to be seen as visible light.

Now we have seen that infra-red radiation can penetrate farther through mist and fog than the shorter waves of visible light, and it is not surprising therefore to learn that as we employ shorter and shorter waves for photography their ability to penetrate the depths of the silver emulsion—which consists of a dense 'fog' of silver halide grains—gets less and less. Accordingly, even a local invisible fluorescence may be detected by photography owing to the fact that the local conversion of ultra-violet light into longer, though invisible, radiation, will result in a greater degree of penetration into the emulsion of these longer rays, and hence a greater eventual blackening on development.

A technique of detecting forgeries has been built up on these observations. By photographing their characteristic fluorescence it is possible to differentiate between different brands of paper, inks, &c., which are visually indistinguishable. Invisible erasures on documents are recorded by the slight difference in the fluorescence excited when they are

exposed to ultra-violet light. Of course, if the erasure has been made by actual scratching away the paper fibres with a knife, the fluorescing substances may be removed, but other methods, also photographic, will then reveal that such


No 4 Prisoner of War Camp
Utopia
Via Callythumpia
Nov. 9th 1944.

My dear Vera,
I am able to send you this letter through the kindness of the Consul of a friendly neutral country. I got your parcel yesterday and was glad of it. The food here is not too bad, considering the blockade you are keeping up, but your Cake added a bit of variety to an otherwise dull menu. We hope — Smith & Carpenter joining with me — that you will be able to get another parcel

Send
a fi l e
in
Cake
. We
hope joining
with you

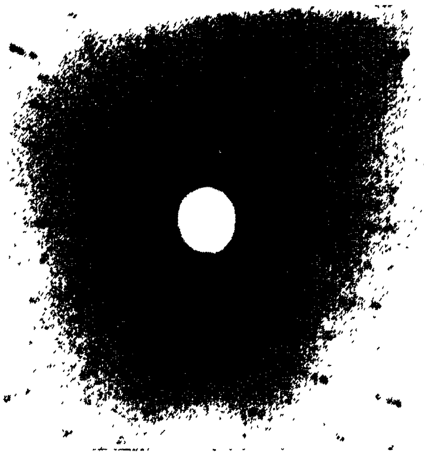
FIG. 26. The original letter was written in ink which was transparent to infra-red radiation. The words forming the hidden message were then gone over with ink which absorbed infra-red rays. A photograph recording only infra-red will therefore discriminate between the two visually identical inks.

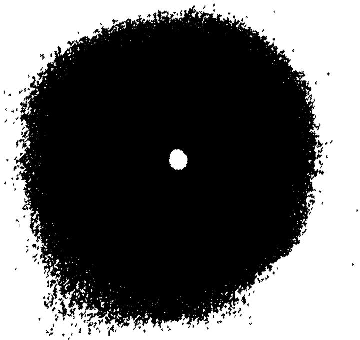
By courtesy of S. O. Rawling

erasures have been made. Colonel Mansfield, who has made a study of this problem, has made the interesting suggestion that the best way to ensure that wills or cheques shall not be tampered with without detection would be to issue them on cheap rather than on high-class paper. Erasure by scratching would then be easy to detect, and the invisible image left by chemical eradicators could be brought to light by ultra-violet photography. In any event, a forger is more likely to make a mess of any alterations he attempts on cheap paper! (Plate 30.)

Photography by ultra-violet rays alone is rarely attempted, although since normal emulsions are naturally sensitive to the ultra-violet, all photographs taken without a filter are in part due to these rays. Fig. 25 shows, however, that

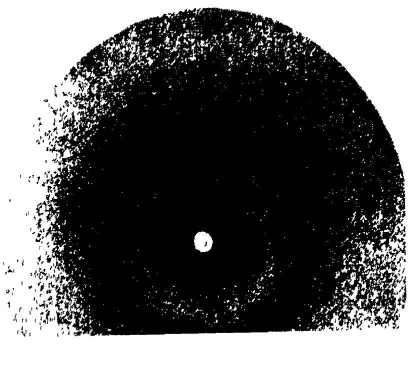
X-ray analysis of crystal structure. The pattern produced as a result of the diffraction of X-rays by the crystal gives the clue to the architecture of the crystal

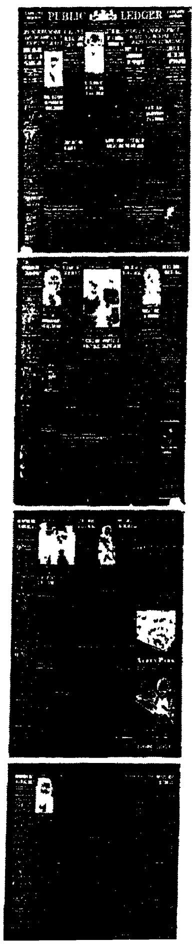




X-ray fibre photograph of human hair

X-ray fibre photograph of human hair stretched in steam to double its initial length (as in 'permanent waving')





Viewing device for examination of film images of Newspaper Library. Enlargement $1\frac{1}{2} \times$ original size of area of newspaper. Lever at left brings any portion of page into view *Courtesy of Eastman Kodak Co., Rochester, N.Y.*

In Russia, village schools are supplied with such film books, each page being projected on a screen during the lesson. As a result, even the smallest schools have a very considerable library despite the paper shortage

the glass used in a photographic lens will absorb all but the near ultra-violet, and it would be necessary to use a quartz lens in conjunction with a filter which is opaque to visible light to obtain a characteristic ultra-violet photograph. A very thin film of metallic silver forms such a filter. Such ultra-violet photographs show glass objects as opaque, white flowers appear black, while, owing to excessive scatter of these very short waves, no shadows will be found in photographs taken in brilliant sunlight, and indeed landscapes will look as though they have been taken in a dense fog.

There are thus two kinds of ultra-violet photography. In one the ultra-violet light itself reaches the plate, in the other the fluorescence, visible or invisible, produced by illuminating the subject with ultra-violet light is photographed. The latter is the most generally useful since, as the wave-length of the radiations striking the plate get shorter and shorter, not only does scatter become increasingly evident, but since gelatine, like glass, is an excellent absorbent for light of very short wave-length, the impression tends to be confined to the surface layers. As radiation of shorter and shorter wave-length is employed, photography becomes increasingly difficult until, when the X-rays are reached, only a fraction of the rays falling on it affect the emulsion, since although X-rays penetrate the emulsion easily enough they are not absorbed by it, and special methods must be adopted to obtain a useful record.

X-rays are electro-magnetic rays of extremely short wavelength which penetrate matter to an extent which depends upon the nature of the substance. Their most familiar application is the examination of the human body in surgical cases, photographs such as that on Plate 31 being obtained by placing the patient between a source of X-rays and a photographic film. The X-rays penetrate the soft flesh structure more easily than the solid bone, and a silhouette picture of the bony structure is therefore obtained on the film. The amount of X-rays which can be passed through living tissue without inflicting injury is limited and would only produce a feeble, surface image on the photographic film. Accordingly, it is not usual to depend solely upon the X-rays themselves to obtain a developable image. Instead, the X-rays, after passing through the subject being examined, fall on a fluorescent screen, and it is the local fluorescence which is responsible for the majority of the exposure. These screens

usually consist of layers of certain metal salt crystals, a familiar example being the luminous hands of some watches. Here the yellowish luminous paint consists of minute traces of radio-active substances embedded in a mixture of fluorescent crystals (frequently zinc sulphide). The X-rays produced during the slow disintegration of the radio-active salt bombard the crystals, causing a visible greenish fluorescence. The films used for X-ray photography are exposed in contact with a screen coated with calcium tungstate.

Wherever the X-rays reach this screen they are converted into actinic, visible rays which, in turn, expose the silver bromide, producing a shadow photograph or 'radiograph' as it is usually called. The X-rays used in surgery are usually produced by a current at a pressure of about 100,000 volts, but with the discovery of a technique for producing X-ray tubes working at about 200,000 volts, radiography has assumed considerable industrial importance. X-rays are now produced of such penetrating power that they will penetrate three inches of steel, whilst the γ-rays, emitted by radium and which are virtually X-rays of extremely short wave-length, have an even higher penetrating power.

The routine examination of aircraft parts, fuses of shells, radio valves, the fitting of shoes, parcels passing through Customs, by X-ray does not necessarily involve photography, since the image cast on the fluorescent screen is visible and will serve instead of a permanent record.

On the other hand, the proper interpretation of the X-ray shadow image frequently requires prolonged examination by an expert who is not necessarily on the spot when the X-rays were employed, and in some cases a photographic record is essential. Thus, it is of vital importance to know whether iron castings on whose soundness human lives may eventually depend have been seriously weakened by hidden flaws such as gas cavities, sand inclusions, or internal cracks. Suppose that an internal cavity $\frac{1}{16}$th of an inch wide exists in the centre of a metal casting 3 inches thick. Then those X-rays which miss the flaw will traverse 3 inches of metal, producing a uniform blackening of the plate, whereas the remainder will pass through say 2 inches of metal, $\frac{1}{16}$ inch of air space, and then $\frac{15}{16}$ inch of metal, and the blackening produced by these rays will be stronger since they have passed through a smaller thickness of metal. Photographic

records obtained in this way will detect variations of less than 1 per cent. in metal thickness, a difference quite undetectable by visual examination of the fluorescent screen. Sometimes a small gas cavity is only of importance when it lies near the surface. It often happens that the crude castings require to be worked upon extensively, and if, after a considerable amount of machining has taken place, a cavity is unearthed, the appearance or usefulness of the finished article is spoiled. However, photography will not only detect such hidden flaws; it will locate them. If two radiographs are made in one of which the source of X-rays has

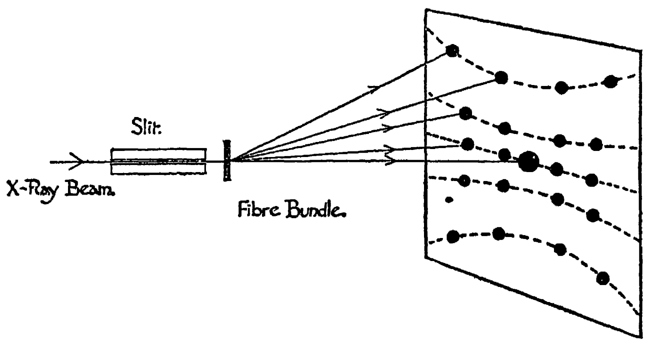


FIG. 27.

been moved aside to a distance corresponding roughly to that between the eyes, these two radiographs can be placed side by side and viewed in a stereoscope (page 39), when a three-dimensional ghost of the casting showing the location of the flaw relative to the surface is seen.

Plate 32 is typical of that branch of X-ray photography which reveals the architecture of crystals. A crystal is simply a pattern formed in space by the atoms or molecules from which it is built up. When X-rays fall on this crystal they are diffracted at definite angles whose relationships depend upon the relative dispositions of the atoms. After passage through the crystal, therefore, the beam of X-rays is split up into subsidiary beams, each travelling in a different direction, and the geometric pattern made by these beams on the plate provides the clue to the arrangement of the atoms forming the crystal (Fig. 27). It is upon the interpretation of such photographs that our present knowledge of the fundamental structure of matter is based, and the method

has been extended to the examination of vegetable and animal fibres. Thus the ability of heat treatment to form 'permanent waves' in human hair has been shown to be explainable in terms of the structure of the keratin molecule as revealed by X-ray photography. The photographs suggest that the keratin molecules consist of long, elastic chains which, on stretching, are pulled out straight and cling together sideways. Heat treatment then throws a series of 'bridges' across between neighbouring chains, forming a kind of ladder, and the individual molecules are thus prevented from coiling up again when the stretching tension is removed.

Naturally, these specialized branches of photography have created a demand for specialized types of photographic material, and the emulsion chemist is continually producing 'curiouser and curiouser' emulsions in an endeavour to meet the requirements of astronomers, physicists, doctors, and engineers. Big photographic manufacturers maintain special departments for this purpose, many of whose productions are of no value to photography in the ordinary sense of this term. By their help, however, the fight against disease and pain, crime and accident, is being carried on with increasing success, whilst nebulae and atoms—the largest and smallest material occupants of space—are continually being trapped into writing more of their cryptic story in grains of silver. Whether this story provides a key to the meaning of the universe, as some philosopher mathematicians have assumed, is of course another matter.

CHAPTER XI

KINEMATOGRAPHY

KINEMATOGRAPHY is possible because of an optical illusion whereby the brain retains an impression of objects viewed for a fraction of a second longer than the eye sees them.

A simple way of demonstrating this persistence of vision is to wave a ruler rapidly to and fro, when its image appears

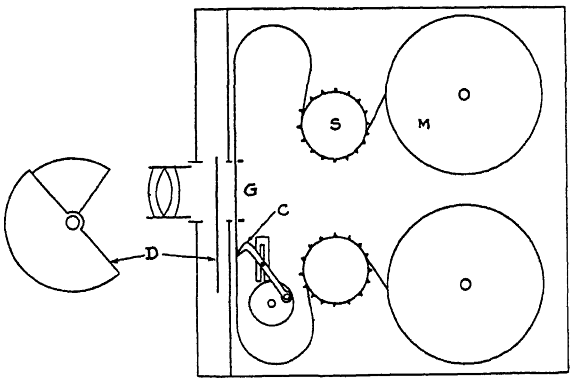


FIG. 28. LAY-OUT OF KINE CAMERA.

to be spread over the whole arc, although actually it can only occupy one point in space at any moment.

This experiment illustrates another important principle of which account must be taken in kinematography—namely, that if we are to obtain a clear impression of what we are looking at, the object must be stationary. Moreover, when this is the case we remain unaware of the carry-over of the image impression. Whilst you have been reading the above you have probably blinked your eyes several times, but it is doubtful whether you have been aware of the fact that, on each occasion, for a fraction of a second you did not see the page at all!

In kinematography a series of stationary snapshots, each representing some phase of movement, is projected on to a screen one after the other, the dark interval between each presentation being so short that before one image has appreciably faded from the observer's consciousness the next

is in position, and the series of still pictures blends together in the mind to give an appearance of uninterrupted motion.

The snapshots, each about $1 \times \frac{3}{4}$ in. in size, are recorded in succession on long narrow bands of celluloid photographic film by means of a camera whose essential features are illustrated in Figs. 28 and 29. *S* is a motor-driven sprocket which, by engaging in perforations on each edge, is continually feeding unexposed film from the light-tight magazine (*M*) into a loop above the 'gate' (*G*), through which the image cast by the lens passes into the camera. It would be useless to draw the film continuously past the exposure station since, if the film was moving during the exposure, the result would be hopelessly blurred as is the case when a still camera is moved during exposure. Accordingly, a claw (*C*) engages into perforations on the side of the film, draws it down into the gate, and then retracts, leaving the film stationary. As soon as the film is motionless in the gate the exposure takes place through a radial slot in the continuously rotating disk (*D*) which acts as the shutter. When light is again cut off from the film by the opaque blade of the shutter moving across the lens the claws re-engage in the film and pull the exposed portion out of the gate bringing a new area of unexposed film into position ready for the next exposure. The time interval between successive exposures is usually of the order of 1/40th of a second, and it would impose too much strain on the film if the intermittent pull of the claw was communicated to the whole length of the film, but by keeping the film looped above and below the gate the sudden starting and stopping is confined to the few inches of film between the continuously running driving and take-up sprockets.

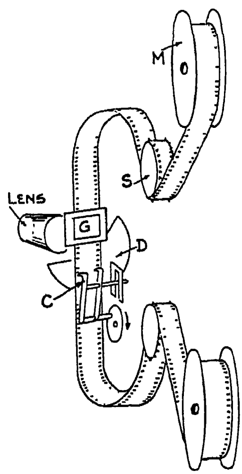


FIG. 29. KINE CAMERA —PERSPECTIVE VIEW.

The exposed negative film is processed continuously by sprocket feeding it in and out of a series of tanks or long narrow cylinders containing the processing solutions, the time the film spends in each solution being determined by the length of the loop of film immersed in each cylinder.

The negative is printed by drawing it, in contact with unexposed fine-grain positive film, past an illuminated aperture. In order that the appropriate printing exposure shall be given to each individual shot, metal studs are attached to the sprocket holes in the negative at those points where an alteration in the intensity of the printing light will

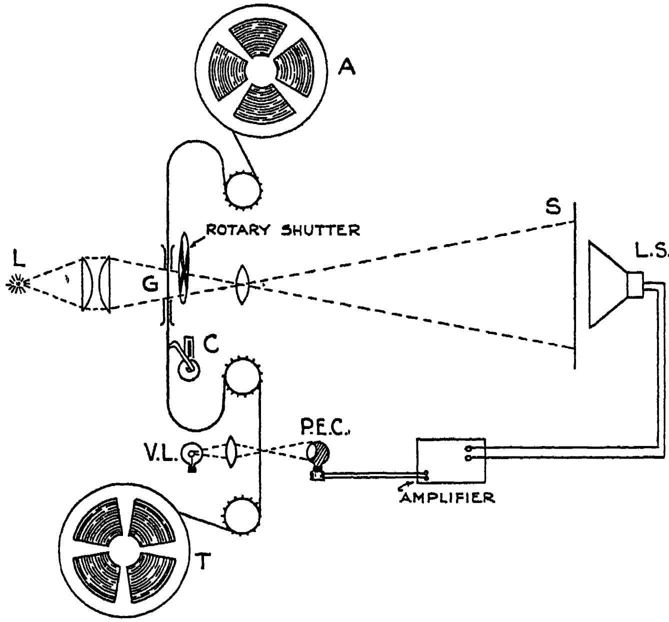


FIG. 30. KINE PROJECTOR.
A, feed spool; G, projector gate; L, arc lamp projecting picture in gate to screen, S; C, intermittent claw mechanism; V.L., lamp illuminating sound-track slit; P.E.C., Photo-electric cell responding to illumination from sound-track; L.S., loud-speaker behind screen; T, take-up spool.

be required if the positive is to be properly exposed. These studs make electrical contacts at the appropriate moment, their number at any point determining the alteration in intensity of the printing light which will automatically follow.

The positive film is projected on to the viewing screen by apparatus whose mechanism resembles in its essentials that of the taking camera. A powerful light situated at *L* (Fig. 30) sends light through the film in the gate on to a rotating shutter. Whenever the film is stationary in the

gate the open sector of the shutter allows an enormously magnified image of the picture framed in the gate to fall on to the viewing screen. As soon as the opaque blade of the rotating shutter passes between the light and the lens the claw mechanism pulls down the next frame into the gate and then disengages, leaving it stationary, whereupon an open sector in the shutter moves across the gate and the image passes through the lens to the screen.

The moving picture seen on the screen thus consists of a sequence of still images separated in time from each other by a dark interval. At least sixteen such images must fall on the screen per second if they are to blend together as a result of persistence of vision, but unless this number is exceeded there will still be present an uncomfortable sensation of flicker—particularly with very bright images. The standard rate of projection is, however, twenty-four frames per second, and matters are still further improved, and a flickerless projection obtained, by dividing the open sector of the shutter into two segments by an opaque blade. An additional interruption is thus inserted into the projection of each frame so that the total number of dark periods per second well exceeds the minimum necessary for a uniform sensation to be registered.

If the movement on the screen is to correspond in speed with that taking place in the original scene it is obvious that the number of pictures projected must be the same as the number exposed in the camera per second. If, therefore, instead of twenty-four exposures in the camera per second, we take double or three times this number, and then project them at normal speed, motion will apparently be slowed down, while if we expose single frames at long intervals, and then project them at normal rate, movements which are in the ordinary way too slow to convey any meaning to us will gain a new significance by this contraction of the time scale.

This alteration of the time scale is of greater importance to the research worker than to the general public, although the slow motion analysis of swift movements such as tennis playing on the one hand and the incredible speeding up of a comedian's movements on the other are always popular with kinema audiences. To be useful in research, however, it is necessary to make apparently enormous alterations to the speed of actions. There is obviously no mechanical limit

Spark photograph. Cup of coffee striking the floor—dropped six feet. Exposure 1/75,000 second at F/16 *Courtesy of K. S. Germeshauser and H. E. Edgerton, Cambridge, Mass*

cycle race spill International News Photo

to the rate at which movement can apparently be speeded up, and by, for example, making one exposure every hour, the life-history of a plant can be recorded as though it were completed in a few minutes. On the other hand, motion cannot be slowed down more than twelve times (which requires 200 pictures per second) with normally designed kine cameras owing to the impracticability of starting and stopping the film at higher speeds without breaking it. This difficulty can be overcome in the case of rotating or vibrating bodies (machinery in action) by illuminating the moving parts with intermittently flashing (stroboscopic) light. If a wheel having several white spokes and one red spoke is revolving rapidly the eye will see a pale pink disk rather than the individual spokes. If this wheel is illuminated with brilliant flashes of light and the interval between each flash is exactly the time required for the wheel to make one complete revolution, the spokes at each flash will be in exactly the same relative position. If the only light falling on the wheel is this intermittent flashing the wheel will therefore appear stationary and the red spoke can be examined or photographed at leisure. If, however, the time between the flashes is slightly longer than that required for one complete revolution of the wheel, the red spoke will make one and a fraction revolutions between each flash, and at each flash will be seen slightly in advance of its previous position. It will therefore appear to be moving slowly in the direction of its actual rotation, and an ordinary kine camera record can be made by the light of the flashes. A little thought will show that during that period while the wheel just falls short of making a complete revolution between each flash, the spokes actually appear to be moving backwards. This stroboscopic effect of slowing down or reversing the apparent motion is frequently seen on the kinema in scenes of motor-cars as they start or pull up. Here, of course, each spoke moves into the position occupied by the one in front during the period between exposures.

This method of slowing down the apparent motion can only be applied to regularly repeated movements of the type described, and in the slow-motion analysis of complicated movements a specially built camera in which the film moves continuously and at high and constant speed is used, the object being illuminated by brilliant flashes of light whose individual duration may be from a thousandth to a

few millionths of a second. The duration of each flash must be extremely small or the picture will be blurred owing to the distance travelled by the moving film during each exposure becoming appreciable. When it is not convenient to use such extremely short exposures, optical systems (such as continuously rotating glass mirrors) which hold the image stationary with respect to the moving film during each exposure are used.

Alterations in the time scale are, of course, immediately apparent to a kinema audience, but there are a number of other tricks whose wholesale employment is largely responsible for the continued popularity of the kinema as a source of entertainment, but whose success depends upon their use remaining unnoticed. Early kinema films were little more than photographed stage plays, but as the competition between the various film companies grew, more and more money was lavished on each production, until eventually the cost of production left little margin of profit. It became usual for large parties of actors and technicians, with wagon loads of equipment, to be transported thousands of miles to locations demanded by the story, while it was often necessary to build most elaborate scenery in which the camera's critical eye could detect no hint of fake which might destroy the illusion of reality.

Hollywood, at that time the centre of the motion-picture industry, was cluttered up with life-size models of ocean liners, Roman palaces, imitation jungles, and half-bankrupt kinema companies. The coming of sound increased production costs enormously, and it became essential to devise means that would enable the majority of the acting to be recorded in studios whose acoustics were under control, and where all unwanted sounds could not enter.

Methods are now employed which not only result in enormous economies in production costs, but render possible effects which would be unobtainable or impractical by 'straight' photography.

The most useful of these devices are those which enable two films taken on separate occasions to be combined on one positive, so that the result as viewed upon the screen is sometimes a source of surprise even to the actors who took part in it! The most obvious ways of accomplishing this proved, in practice, the most difficult to perfect and is called 'rear projection'. The actors perform in front of a

large translucent screen on which is being projected from the rear a film of any desired background. The kinema camera in photographing the actors re-records the background film, and in the combined result they appear to be performing in the surroundings where this film was made. In consequence, instead of transporting the whole cast and equipment to Africa, for example, it is only necessary to send a small photographic unit to make the background scenes. One of these might include a 'close-up' of a charging elephant taken in comparative safety by means of a

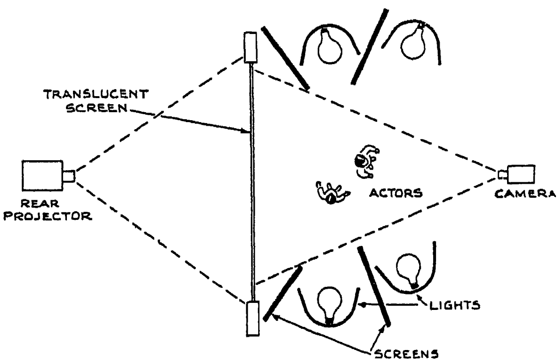


FIG. 31. TOP VIEW OF STUDIO LAY-OUT FOR BACK PROJECTION.

telephoto lens, and the hero's bravery when, on the screen of the picture theatre, he defends himself from the animal with his broken rifle is explained. The only fear in his mind at that moment is of breaking the fragile screen as he lunges at the image on its surface!

Although rear projection is becoming increasingly important, its scope is sometimes limited by the fact that the background image will only be clearly visible when the screen is kept in comparative darkness, and it must therefore be shielded from the lights that are used to illuminate the actors in front of it.

In the Schüfftan system the background is introduced in a different manner. Immediately in front of the camera lens is placed a mirror at 45°, whose silvered surface reflects into the lens either a still photograph or a kine-film which is projected on its surface from the side. A portion of the silvered surface is removed, and through the window so formed the camera photographs action taking place in front

of the lens. The resulting negative, therefore, records over parts of its surface the image projected on to the mirror from the side, and over the remainder the subjects in front of the camera. In a typical Schüfftan negative the top half of each picture will consist of the scenery so projected from the side of the camera, and the bottom half of action taking place in front of it, the junction between the two being cunningly chosen to coincide with those convenient outlines or shadows where its presence will be least noticeable.

Another highly ingenious method of multiple image photography—the Dunning process—can only be properly understood after a study of Chapter IX.

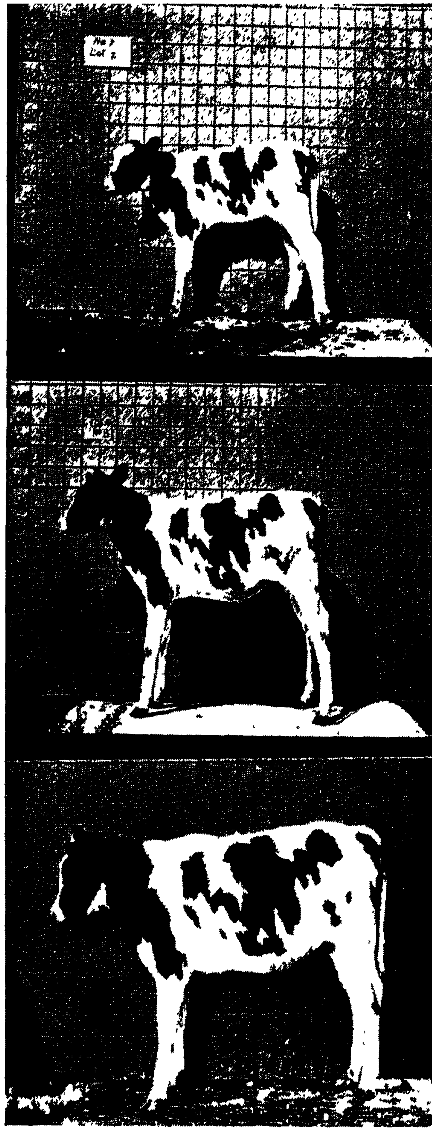
In this system a film of the scenery in which it is required that the acting is to appear to take place is toned a transparent yellow, and is threaded into the camera in front of a panchromatic negative film. The actors are lit with yellow light and perform in front of a brilliantly lit purple-blue background. Wherever yellow light is reflected from the actors it passes unhindered through the transparent yellow printing mask and records as an image of the actors on the panchromatic film. Wherever the blue light from the background meets the yellow image in the camera gate it is absorbed, since blue is complementary to yellow, and as a result, so far as the blue light is concerned, the yellow image acts as an ordinary black silver image would in that it stops light in proportion to its density at any point, and a print of the yellow image therefore records on the rear film wherever blue light falls. As the actors move in front of the blue background they prevent blue light from reaching the films, and so prevent the 'scenery' film from printing, their own yellow-lit figures recording in its place.

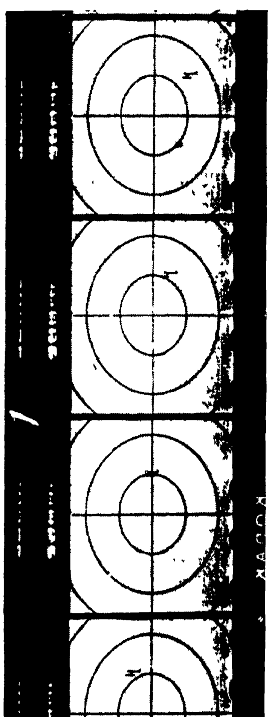
Apart from the convenience of such multiple photography in providing spacious backgrounds for studio shots, it enables small-scale model scenery to be used in place of the real thing. Thus H. G. Wells's fantastic film, *Things to Come*, required scenes in enormous factories housing huge machines. The cost of building sufficiently convincing scenery on a life-size scale was avoided by photographing small models and projecting the film as a moving background behind the artists.

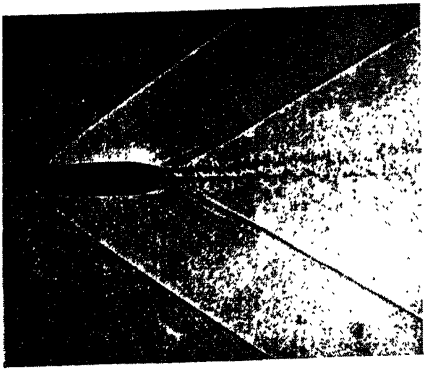
Another important device is the optical printer, in which, instead of printing by contact, the image of the negative in one gate is thrown by a lens on to unexposed film in an

Photographic studies of experimental calves. The square background lends itself to measuring progressive development

University of Alberta, Department of Animal Husbandry

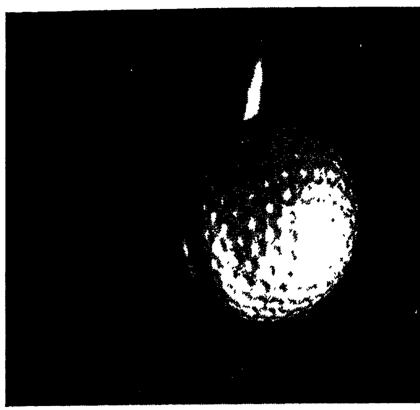


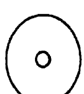




A bullet photographed in flight. Bullets travel at about 1,000 miles per hour, and the velocity can be calculated from the shape of the compression wave silhouette. *Peters Cartridge Co., Cincinnati, U.S.A.*

High-speed photograph, 1/75,000th second. Golf ball photographed at moment of impact with club. Note flattening of ball. High intensity spark discharge automatically fired by interrupted light beam and a photo-electric cell. Output of cell amplified sufficiently to trip the spark. *Photograph by H. E. Edgerton and K. J. Germeshauser, Massachusetts Institute of Technology*





A Microphotograph of a portrait of J. N. Niépce, by Professor Goldberg. Diagrammatic representation of the slide on which the photograph was produced by Professor Goldberg. The portrait is a minute speck in the centre of the inner circle, into which 300 more of a similar size could easily be placed

The actual portrait of Niépce, enlarged from Professor Goldberg's original, so that the area covered is increased about 160,000 times. The extremely fine grain of the emulsion accounts for the comparatively small amount of

opposite gate. Originally devised to enable full-scale films to be reduced on to sub-standard stock, this method of projection printing is now used to produce an amazing assortment of fakes. Masks can be inserted between the negative and positive film to make the 'wipes' by which one scene rolls, glides, twists, or smears into the next. The negative can stand still while the positive is advanced to give fake ultra-rapid or delayed action shots, and so on. The film, *The Invisible Man*, was produced almost entirely by

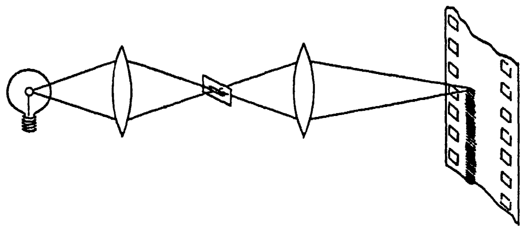


FIG. 32. VARIABLE DENSITY SOUND RECORDING.

multiple image photography in conjunction with optical printing.

Sound Recording. Sound consists of waves in the air whose impact on our ear-drums causes them to vibrate, the rate of vibration determining the 'pitch' of the sound. The lowest and highest notes which a normal ear will recognize as such are the result of vibrations of 16 and 10,000 per second, and any surface vibrating in air at frequencies between these limits is emitting audible sound. A microphone is a kind of mechanical ear in which these same vibrations are translated into minute electrical currents. These currents, when suitably amplified, can be used to vary the nature of a beam of light which is focussed on a photographic film. Suppose, for example, the filament of a glow-lamp is focussed by a lens on to a horizontal slit behind which the film is travelling. If we use the varying electric currents from the microphone to vary the intensity of glow-lamp filament, the image of the slit cast on the film will vary in brightness, and a track of the width of the slit but of varying density will be recorded on the film (Fig. 32).

Alternatively, we could use a constant source of light, and employ a shutter to vary the width of the slit. This shutter sometimes takes the form of a taut wire which, in its position of rest, prevents light from the slit reaching the film. The wire

lies between the poles of an electro-magnet, and when currents from the microphone flow through it the wire moves aside in response to the vibrations in the electro-magnetic field so produced, the amount of its deflexion determining the amount of light which reaches the film. If the wire, instead of being parallel with the slit, crosses it at an angle, its vibrations will alter the apparent length of the slit so that the record on the film, instead of being of variable density, will be a wavy track of constant density, but whose width

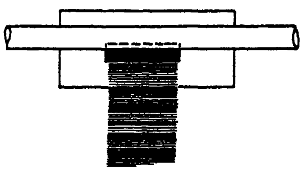


FIG. 33. VARIABLE DENSITY.

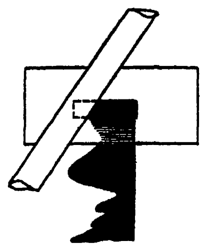


FIG. 34. VARIABLE AREA.

at any point is proportional to the amplitude of the original sound vibrations (Figs. 33 and 34).

In order that each variation in intensity or area of the sound-controlled light source may be individually recorded, it is necessary that the portion of the film on which sound is recording be moving continuously past the slit. Accordingly, when, as in news cameras, the sound and picture are both recorded on the same film, the sound record is made on the film after it has passed the two sprockets between which its travel is intermittent. The film is moving past the slit at about 1 foot per second, and if a distinctive record of each individual wave is to be obtained the slit must not be more than 1/1,000th of an inch wide. It would be very difficult to keep an actual mechanical slit of such dimensions free from dust, &c., and accordingly the tiny thread of light which actually falls on the film is actually an optically reduced image of a conveniently large actual slit.

There are many different systems for converting the original sound waves into either variable area or variable density tracks on the film, each of which has its own peculiar advantages.

In order to reproduce the sound, a beam of light is projected

on to the film record in the form of an optical image of a slit, and the sound track forms a photographic mask that controls the amount of light transmitted by the film at any point. The modulated light then falls on a photo-electric cell, a kind of synthetic eye, which converts the various intensities of light back into varying electric currents. These, when sufficiently amplified, actuate the diaphragm of a loud speaker, and so re-construct the original sound (Fig. 30).

On the positive film as projected the sound record is printed as a track 1/10th of an inch wide alongside the picture areas, but it is not, of course, necessary that this track should have been recorded on the original picture negative. In the studio, where portability of the equipment is a minor consideration, it is customary to employ two films, one to receive the picture and the other to record the sound, the sound-recording apparatus being quite distinct from the camera.

In order to ensure that, when these two different types of record are printed alongside each other on the final positive, they shall be properly synchronized, it is usual to commence each shot with a visible and audible warning of distinctive character. For example, standing in front of the picture camera an assistant may clap together two pieces of wood, at the same time displaying a board and speaking aloud particulars which will identify the shot. A similar board is photographed by the sound camera alongside the early part of the sound track and identifies the shot in question, while the exact frame in which the two pieces of wood meet is easily found on the picture record, and the 'clap' causes a quite distinctive smudge on the sound track.

The coming of sound films necessitated radical changes in the technique of producing, casting, staging, and processing of films, and helped to break the virtual monopoly which America had established in the kinema industry. Cameras had to be re-designed to run as silently as possible; hissing arc lamps gave way to 'inkies'—the giant 10,000 watt incandescent lamps. The studios, which in the silent days had been the noisiest places imaginable, were lined with sound-proof packing; and now, when the red light warns the visitor that 'shooting' has commenced, he will be well advised not to risk dropping even the proverbial pin.

Considerably greater attention had to be paid to the photographic quality of the film itself, for faults in processing tolerated or unnoticed in the picture were unpleasantly obvious in the sound. Even with the most painstaking care, pre-talkie technique could not prevent every operation in the processing of the film from contributing its quota to the scratchy, crackling background noise, and development by inspection of films wound on racks like clothes-horses gave way to automatic processing.

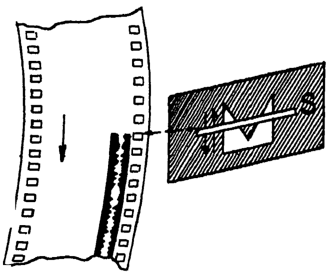
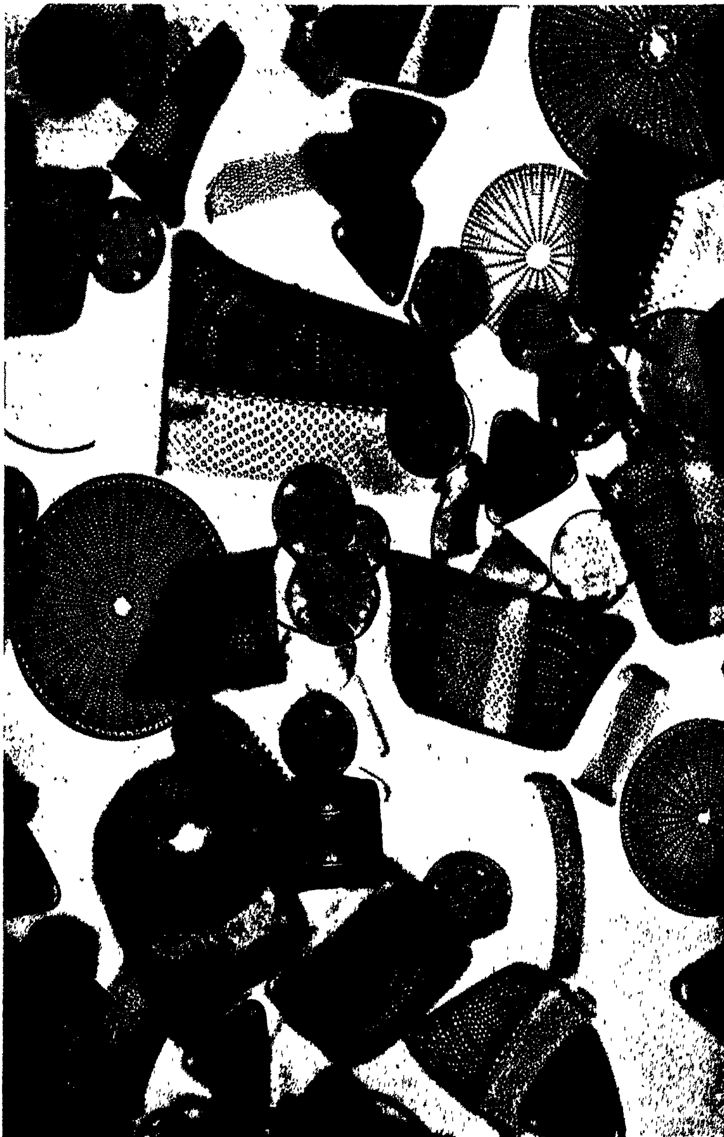


FIG. 35. TWIN VARIABLE AREA TRACK PRODUCED BY VIBRATING FORKED BEAM FALLING ON SLIT.

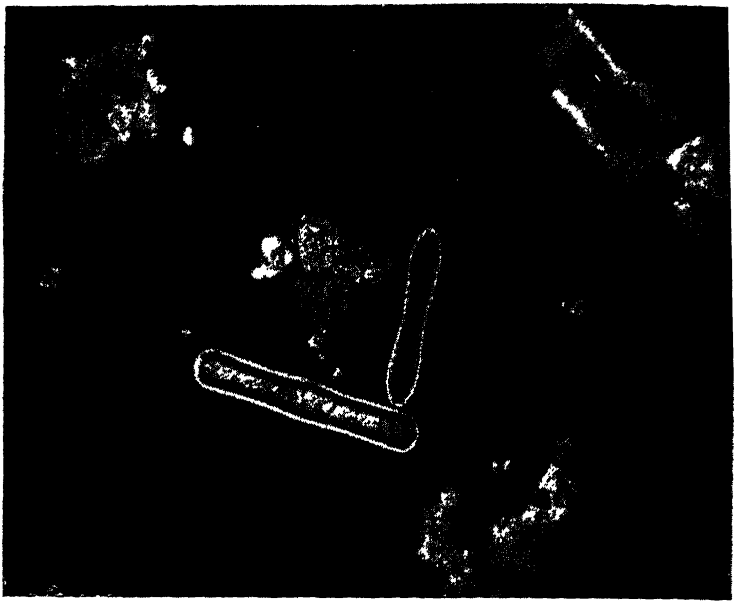
It must be remembered that whereas the picture itself is enlarged from film to screen approximately 300 times, the sound is amplified several million times from the initial impulses of the photo-electric cell to the point where it is projected from the loud speakers; and a flaw on the film which, on the picture area, results merely in a momentary and perhaps unnoticeable spot of negligible size, may produce a deafening crash if it occurs on the sound record. However carefully the film is processed it is difficult to avoid tiny particles of foreign matter, minute scratches which accumulate dirt, &c., from appearing on the transparent area of the track. As every foreign particle passes in front of the exploring beam it cuts down, for a fraction of a second, the intensity of the light, and it is the presence of a considerable number of such interruptions which results in the, so called, 'ground noise'.

Variable density records are therefore rendered 'noiseless' by giving a preliminary, slight general exposure to the track so that the final variations of density which constitute the sound record are uniformly overlaid by a thin veil of fog in which any inequalities due to foreign matter are buried.

Incidentally, this preliminary fogging ensure that the whole of the sound record lies on the straight line portion of the characteristic curve of the emulsion, where density increases proportionately with exposure, thus minimizing the risk of sound distortion due to the photographic characteristics of the material.



Deep-sea mud × 152 *Courtesy of August Kreyenkamp*



Like an example of Modern Design: Diatoms in a reservoir moving into action against bacteria

Courtesy of British Instructional Films, Ltd.

In variable area records it is now customary to use a double track produced by methods such as those shown in Fig. 35. Here, it is the relative width of the transparent gap between the two tracks which determines the pitch of the sound, and the width of this gap is automatically controlled so that at any moment it is only just wide enough to record the relative variations in the shapes of the curves. In quiet sounds, therefore, where the background noise would be most obvious, the width of the gap is narrowed considerably so that there is a minimum of transparent area and therefore of foreign particles. Fig. 36 shows a loud sound followed by a quiet sound in an ordinary and a 'squeezed' double track. The progress which has been made in sound-film technique in ten years is staggering, and so intensive is the research that is being directed towards solving outstanding problems that improvements are out of date almost before they have been applied.

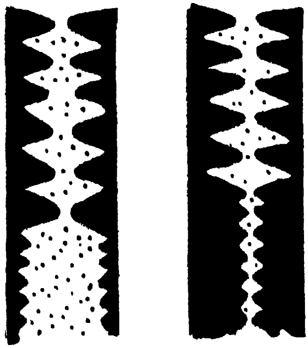


FIG. 36. VARIABLE AREA SOUND TRACKS.

A. Normal record of loud sound followed by soft sound.

B. Squeezed track record of loud and soft sound. Foreign matter on the two tracks is indicated by dots.

The incredible speed at which advances are made in kinema technique is partially explained by the size of the industry. It commands more capital and employs more people than all the rest of the photographic industries combined, and in the U.S.A. it is believed to be larger than any other single industry in the country. The U.S.A. consumes 400,000 miles of kine-film every year, while in England one company alone, by producing 1,000 running miles of film every week, only meets a portion of the demand of the British kinema industry. In 1934 there were 57,000 kinemas, three-quarters of which were equipped for sound, operating throughout the world.

Standard film is 35 mm. wide, the picture area when no sound track is present being $1 \times \frac{3}{4}$ in. When a sound track is present the picture frame is reduced to $\frac{8}{10} \times \frac{5}{8}$ in. Standard film has nearly always a celluloid base, and stringent

regulations govern its use in theatres owing to the almost explosive fierceness with which it burns when once ignited. The fire risk can be overcome by using cellulose acetate in place of celluloid as a base, but the acetate is more expensive, and the earlier forms were liable to shrink slightly with time, and in consequence to present difficulty in projection. In a picture theatre the kine frame is frequently projected on to a 24-ft. screen, representing a linear magnification of 300, and a superficial magnification of 90,000 times. Accordingly, traces of unequal shrinkage which would have negligible effect on the steadiness of a relatively small enlargement will result in a quite noticeable jumpiness on the theatre screen. Recent improvements in the manufacture of cellulose acetate base have largely overcome this defect, and 'non-flam' film is gradually gaining a footing in the 35 mm. industry, while for amateur kinematography (in which the drawbacks mentioned are scarcely detectable owing to the smaller scale of working) its use is almost universal.

Sub-standard Film. Even if they were presented with the equipment, few private people could afford to indulge in 35 mm. kinematography as a hobby. By the time their pictures were projected on the screen they would have cost something like £1 per minute in film alone! On the other hand, the amateur does not require to project a picture 20 feet wide, and in the last ten years equipment has been designed for use with sub-standard sizes of non-inflammable film, whose running cost is still further reduced by using the so-called 'reversal' system of processing. In this system, instead of developing the film exposed in the camera to a negative which must be printed on to a separate film, it is converted directly into a positive. The usual method of accomplishing this is to develop the exposed negative image, and then, instead of fixing out the unexposed silver halides as in the normal negative-positive system, to dissolve out the exposed metallic silver, by treating it with a suitable oxidizing bath. The undeveloped silver bromide which remains in the film is now exposed to light and treated with developer, giving the positive image.

The stages in this process are shown in diagrammatic form in Fig. 38, which shows the same area on a film after each operation.

In the form described the reversal process will only give

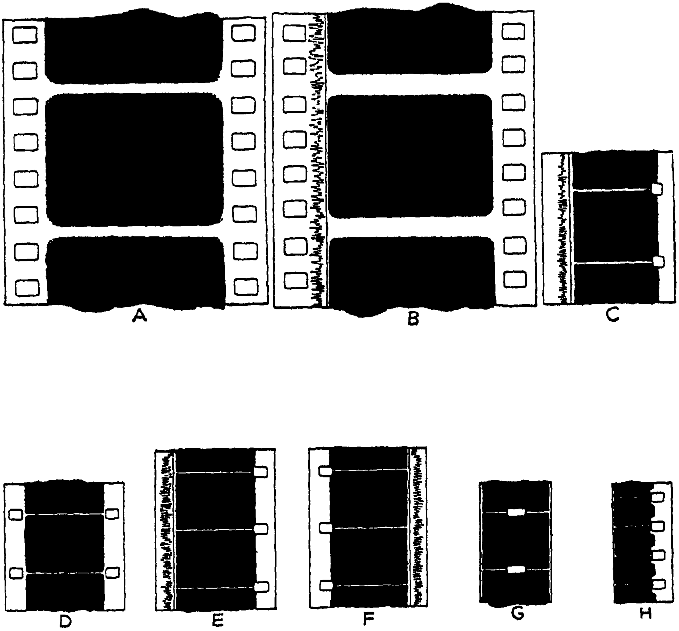


FIG. 37. STANDARD AND SUB-STANDARD KINE-FILM.
Actual size.
(Picture area shown in black)

A. 35 mm. Silent Film; B. 35 mm. Sound Film; C. 17·5 mm. Sound Film; D. 16 mm. Silent Film; E. and F. Two different standards of 16 mm. Sound Film; G. 9·5 mm. Silent Film; H. 8 mm. Silent Film.

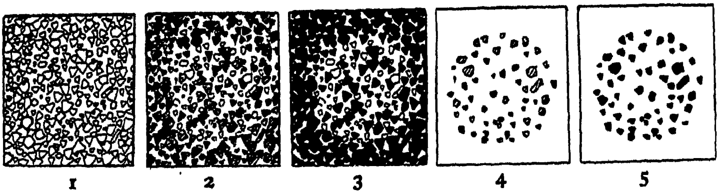


FIG. 38. REPRODUCTION OF A GREY DOT OR POINT BY THE REVERSAL PROCESS.

1. Unexposed emulsion. 2. Exposed emulsion. The light-struck grains are indicated by shading. 3. First development. The light-struck grains have been converted to black silver, giving a negative image. 4. The developed silver grains have been dissolved away and the remaining grains exposed to light. 5. The grains fogged by this second exposure are developed to form the final positive image.

a satisfactory positive over a small range of exposures, since, if the original exposure in the camera is too short, the negative image which is obtained on the first development, although perhaps quite satisfactory as a negative exposure for printing from by the negative-positive system, will leave on bleaching an excessive amount of silver halide, and the final image will be too dark, while if the camera exposure was too long, there will not be sufficient silver halide left after bleaching to give a dark enough positive. The results, in fact, could scarcely be more satisfactory than those which would be obtained in ordinary photography if we printed all the varied types of negative which even the most careful technique produces on one grade of paper using one fixed exposure. There are several methods available for compensating for this defect in the simple reversal process, but as they consist for the most part in modifying the final stages of processing after examining the nature of the first developed image, they are of greater value to those who use the process for mosaic screen colour photography than to makers of kine-films, since it is not convenient to inspect and then give special treatment to individual shots of which there may be twenty or so in one film.

There is, however, an ingenious system invented by the Kodak Company which automatically compensates each individual shot for all but the grossest errors in exposure.

In this controlled reversal system the film, having been developed to a negative and had its silver image bleached away, passes between a source of infra-red rays and a photo-electric cell. The amount of silver bromide left in each frame controls the amount of infra-red light falling on the cell, and the electric currents produced by the cell under the stimulus of these rays operate a galvanometer vane which, as it moves aside in response to the currents received from the cell, permits light to fall on the film, the amount of this exposing light being thus proportional to the amount of infra-red transmitted by the film. If there is a lot of silver bromide left in any particular shot, it is a sign that the film was under-exposed; very little infra-red passes through the frame, and therefore very little light is permitted to reach the film during the second exposure, and vice versa. In this way, each frame receives just that exposure necessary to render the right amount of silver halide developable, and after this second development any unwanted silver halide is

removed by fixation. Of course, this system necessarily treats each frame as though it were an 'average' subject; and if, for example, a shot is taken in which a large proportion of each picture would properly be rendered as very dark indeed—e.g. a close-up of a blackboard with a title on it—the automatic controlled reversal process would, on finding a large amount of silver halide left in the frame, proceed to treat it as though it were under-exposed and the result would be greyer than is desirable. Such exceptional shots can, however, easily be intensified individually, and then spliced back into the film.

Most manufacturers process sub-standard film on continuously running machines consisting of a series of tanks which carry racks with rollers, by means of which the film is fed continuously through the solutions. The machines are entirely automatic, the films being fed in as they come from the customer, and taken out of the drying chamber as positives ready for projection. In little more than an hour from the time the film enters the machine it is ready for projection, and each machine takes a new film every five minutes.

In 1934 there were 150,000 sub-standard cameras in use in Britain, 300,000 in France, and over 1,000,000 in the U.S.A. The majority of these cameras use either 16 mm. or 9·5 mm.

16 mm. Film (Fig. 37, No. D). This size, first introduced in 1924 by the Kodak Company, is the most popular with the serious amateur because the equipment available for work with it is nearly as comprehensive in its variety and scope as it is for the 35 mm. professional size. 16 mm. film is now issued in 50-foot and 100-foot lengths by all the big manufacturers. The film is available as reversal or negative-positive stock, and the selling price normally includes the cost of processing by the manufacturer, to whom it is returned after exposure for this purpose. Recently 16 mm. sound and picture cameras and projectors have been introduced, the sound track either encroaching on the silent picture area as with 35 mm. film, or one row of perforations is abandoned, leaving 1/10th of an inch strip down one edge of the film on which a full size sound-track can be accommodated (Fig. 37, No. E).

Colour kinematography is possible by several different systems.

16 mm. film is rapidly growing in importance to industry. It is used to record the results of research, to eliminate long reports to distant executives on such matters as breakdowns in plant, &c., to train new operatives in the handling of machinery, and to amplify the traveller's story of his firm's products.

Recently special cameras which expose one frame at a time have been installed to photograph the invoices and receipts of a business, and so enable a record of masses of paper to be accumulated in order and in negligible space.

Libraries are experimenting with the use of such cameras for photographing newspapers and documents. Reference to any particular record is made by putting the film in a special projector which automatically winds the film to a pre-selected frame, and then throws the life-sized image of this frame on to a viewing screen.

The growing importance of kinematography in education is shown by the fact that in 1934 half the schools in New York were equipped with 16 mm. projectors. Data collected to date show that pupils taught with the aid of the kinema obtain a better grasp of subjects in a shorter time. People of all ages remember a picture better than sound, and sound better than writings. Indeed, words are only a rather complicated form of thought picture and most grown-ups can remember the illustrations in their school-books when the written pages have faded from memory.

The League of Nations has recently set up a bureau in Rome where the best educational films are being classified and catalogued. Arrangements are being made for the international exchange of these films with a minimum of formality or restriction.

The experiment may prove to be a valuable step towards a better world understanding and, in England, the British Film Institute is now engaged in collecting representative material for this purpose.

9·5 mm. Film. Shortly after the introduction of 16 mm. film the Pathé Company marketed amateur equipment for an even smaller size, e.g. 9·5 mm. The picture area of this film is only slightly smaller than that of 16 mm. owing to the use of a single central perforation between each frame, allowing a picture the full width of the film to be obtained (Fig. 37, No. G). This equipment is of great appeal to the

amateur of limited means since the first cost is relatively low. On the other hand, the running costs are very nearly the same as for 16 mm. The reason for this is that in both sizes there are the same number of frames per foot, and the same number of frames per second (sixteen) are projected on the screen. Screen time is the only fair basis of comparison and, in the case of orthochromatic film, the cost per minute is 4*s.* on 9·5 mm. and 4*s.* 10*d.* on 16 mm. In the case of negative-positive stock the 9·5 mm. is actually dearer than 16 mm.

9·5 mm. film is obtainable as negative-positive or reversal material, but the latter has somewhat limited exposure latitude since methods such as that described on p. 136 for automatically compensating for errors in exposure are not employed by the firms who process 9·5 mm. film. On the other hand, the 30-foot lengths in which the film is issued can, if desired, be processed by the amateur himself, and the system has therefore considerable appeal for those who like to do everything for themselves, while the intelligent use of exposure meters will ensure that the majority of shots are well within the latitude of the film. Here again there is a wide variety of apparatus and supplementary equipment from which to make a choice, and the enthusiastic 9·5 mm. worker can produce results which on the screen compare favourably with 16 mm. film.

From time to time various other sub-standard sizes of film have been introduced, but only two of these need be mentioned in a general review. The Pathé Company have issued a 17·5 mm. combined sound and picture film which has perforations on one side only, there being one perforation per frame. This film is intended chiefly for use in education, and libraries from which these films can be borrowed have been established.

Many people think that it is a pity that the industry as a whole could not have agreed to limit the number of different sizes of sub-standard film to two or three, and this might have been possible if an authoritative International Standards Committee had been appointed early enough in the history of the kinema. As it is, the multiplicity of film sizes and methods of recording sound is limiting the facilities of which the owner of one type of camera and projector can take advantage. Some projectors will cope with at least two different widths of film, but the different positions of the

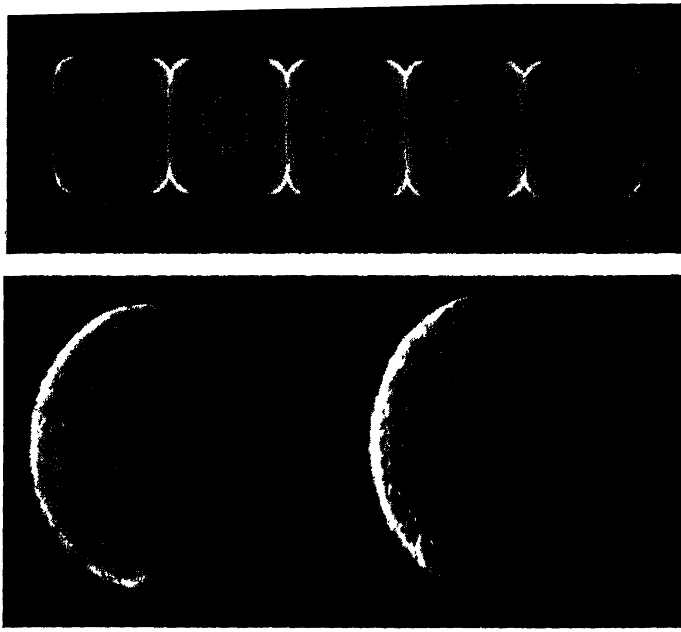
sound track which America, France, and England have standardized is a rather more difficult problem.

In the opinion of the Kodak Company many photographers were frightened away from adopting 16 mm. kinematography because the existence of very expensive cameras, lenses, and other supplementary equipment suggested that the cheaper, simpler models were unduly limited in scope. Accordingly, they are now marketing an 8 mm. film, and it is their stated intention to refrain from whetting the amateur's appetite by keeping the 8 mm. cameras and projectors in as simple a form as is practical. The camera is loaded with a specially perforated 16 mm. film, and is so designed that four exposures are made in the area of one 16 mm. frame. The film (25 feet in length) travels through the camera twice, first recording down one half of the film and then down the other half. After processing, the film is slit down the centre giving 50 feet of 8 mm. film. Full advantage is taken of the improvements in the direction of fine-grain emulsion manufacture made in recent years, and the tiny pictures, each 5×4 mm., give excellent quality when thrown on a screen 30×20 in., while the running cost is only 2*s.* 6*d.* a minute as compared with 4*s.* 10*d.* for 16 mm.

COLOUR KINEMATOGRAPHY

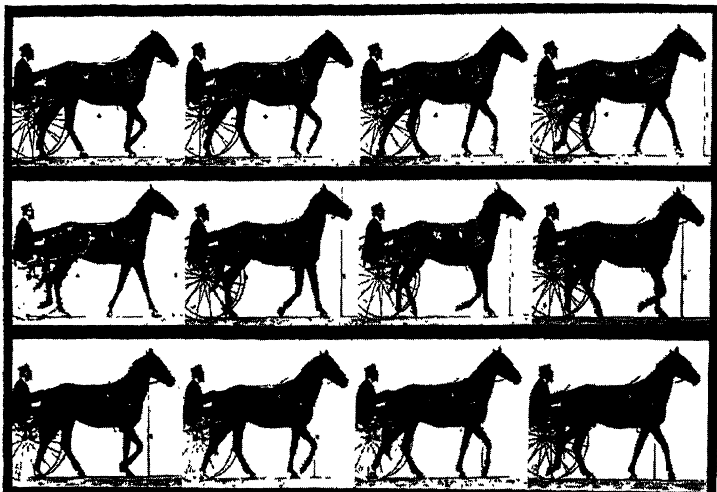
Several of the systems of colour photography described in Chapter IX have been applied to colour kinematography. The earliest types of colour kine processes were a compromise in which the spectrum was split up into two rather than three parts—the blue record being sacrificed. These compromise processes never attained any real popularity since the colour rendering was limited, and interested readers are referred to text-books mentioned in the bibliography for further particulars. In 1933, however, the Technicolor Company introduced a three-colour subtractive system, and interest in colour kinematography revived.

One of the biggest difficulties in three-colour subtractive kinematography is to obtain the three negatives—a problem that is not yet satisfactorily solved. It is easy enough to design on paper kine cameras which would expose three negatives through the three filters at the same moment, and the difficulty is not so much to devise ways of dividing up the light entering the lens between three films as to do this in practice with sufficient precision, so that when the three


Flame photographs

Courtesy of Dr. Oliver C. de C. Ellis, F.R.P.S.


Copernicus : A lunar crater taken



Animal locomotion. One of the early plates from the studies of movement, by Eadweard Muybridge *Courtesy of Royal Photographic Society*

images are brought together again and thrown at huge magnifications on to the screen, they will register properly.

While they were feeling their way, Technicolor experts avoided the difficulty by limiting their three-colour process to the making of colour cartoon films—the Silly Symphonies of Walt Disney. The problem of making the three negatives was thus enormously simplified, for such a cartoon is made by photographing a sequence of coloured drawings, and the time factor is no longer of importance. Each drawing is photographed three times on to the negative film through red, green, and blue filters in turn; then, by means of an optical printer, all the red records are collected on to one positive, the greens on to a second, and the blues on to a third. The positive films are developed and processed in such a manner as to produce positive relief images in hardened gelatine. They are then soaked in dye solutions of colours complementary to those recorded on the negatives, and each film in turn is brought into contact with a film of plain gelatine to which the dye image is transferred in register. How much the popularity of the Silly Symphonies is due to the use of three-colour Technicolor, and how much to Disney's genius, remains to be seen, but the enthusiasm with which the cartoons were received has resulted in several companies turning their attention to colour, and many patents for cameras and processes have recently been registered. As already explained, however, it is one thing to make satisfactory, critically sharp negatives on a cartoon camera, and another to make such negatives under ordinary studio conditions.

Fig. 39 shows in diagrammatic form the principle of the camera which is at present being used for 'living' subjects as opposed to colour cartoons by the Technicolor Company. Light from the lens *L* falls on the gold-flecked surface separating the two glass prisms *P*. The rays transmitted by the semi-gilded mirror pass through a filter which absorbs all but green light and falls on the single film travelling through the gate at *G*. This film therefore records only the green light reflected from the subject. The light reflected by the mirror passes through a pink filter which absorbs green light to the gate *BR* through which two films are passing face to face. The light falling on this 'bipack' consists, therefore, of the blue and red groups of rays reflected from the subject.

The film nearest the lens is sensitive to blue light and therefore records the blue rays falling on it. This film is, however, insensitive to the red rays, but, as it has a specially transparent emulsion, these red rays are able to pass through it and record on the rear film. In this way all three records are made at once, though with some sacrifice of definition in the case of the rear bipack image owing to scattering of

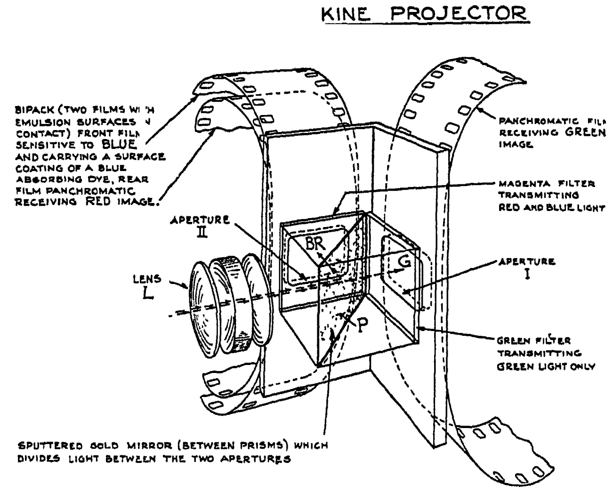


FIG. 39. THE OPTICAL SYSTEM USED IN TECHNICOLOR'S CAMERA.

The gold-flecked mirror on the face of the prism splits the light from the lens into two beams. The rays transmitted by the mirror pass through a filter which absorbs all but green light which then records on the single film. The light reflected by the mirror passes through a pink filter which absorbs green light. The blue rays passed by this filter record on the front film of the bipack, whilst the red rays pass through the front film which is not red-sensitive and record on the near, panchromatic film.

the red rays on their way through the emulsion of the front film. The coloured halo round fine detail which is more noticeable in 'long shots' is due to this cause.

The only additive system that has so far been used commercially for 35 mm. photography is Dufaycolor. This process has already been described, and its advantage as a kine process is chiefly that no special colour camera is required, the film being exposed in the ordinary studio type of kine camera. The printing process employed—which in effect amounts to re-photographing the master film on to another Dufay film, involves fewer operations than

subtractive printing, and in the long run, therefore, it may prove commercially cheaper to produce. Against these two positive advantages, however, must be set the fact that all additive processes require considerably more light during projection. Thus, as has already been explained, whereas a white in a subtractive film is represented by clear celluloid, in additive processes it is built up of red, green, and blue elements each of which owes its colour to the fact that it is absorbing approximately two-thirds of the lights which fall upon it. In view of the intensive research that is now proceeding on both additive and subtractive kine colour systems, it is foolish to prophesy which will eventually prove the most successful. Probably both systems will survive, and just as room is found in the photographic industry for celluloid and glass as a support, for variable area or variable density sound recording, probably both additive and subtractive systems of colour kinematography will find remunerative fields for expansion.

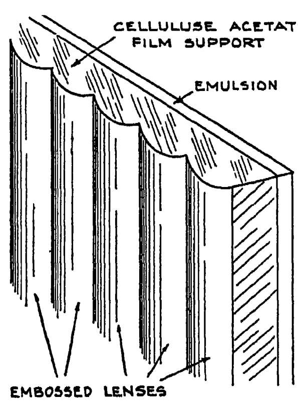


FIG. 40. PERSPECTIVE VIEW OF LENTICULAR KINE-FILM ENORMOUSLY MAGNIFIED.

At all events, the amateur is fortunate in that he can try both systems for himself, for both additive and subtractive three-colour 16 mm. kine-film is available. Indeed, owing to the fact that most amateurs require only one copy of their films, commercial systems are available to the amateur that have not so far found application to professional kinema films. The most interesting of these from a theoretical point of view are the Kodacolor and Agfa-color lenticular systems available only as 16 mm. film.

The Lenticular Process. A piece of lenticular film looks just like an ordinary black-and-white film. If, however, the rear surface is closely examined it will be found that the film base has a 'matt' appearance, due to the fact that during manufacture it has been embossed with a multitude of tiny corrugations. The film is threaded in the camera with the embossed surface facing the camera lens,

while in front of the latter is placed a special banded filter consisting of three stripes of red, green, and blue glass. The corrugations act as tiny cylindrical lenses, and form on the emulsion a multitude of images of this filter through which light from the subject must pass on its way to the emulsion.

In Fig. 41 (A) is a front view of the banded filter, and (B) is a horizontal section showing in simplified form the optical arrangement employed. In this diagram it is assumed that

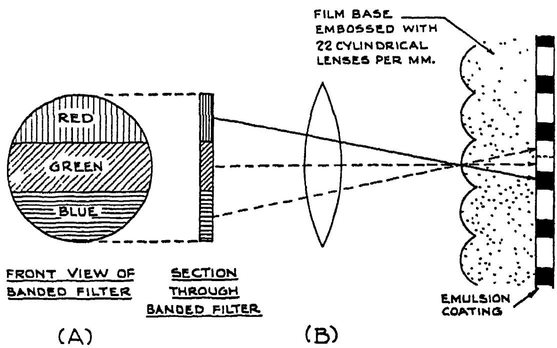


FIG. 41.

a red object is being photographed. All rays passing through the red segment of the filter are brought to a focus within the area marked in black in the emulsion, and the path of one such ray is shown as a solid line. Since the blue and green filter segments will absorb red light, the remainder of the emulsion on which the cylindrical element in question is focussing these segments of the filter will remain unexposed. Accordingly, the width of each of the minute areas of emulsion behind each little lens can be divided into three parts, each related to one of the filter areas, and in the case being considered only one of these parts, that where the red rays are brought to a focus, is exposed.

When the exposed film is developed and reversed to a positive these exposed areas will become transparent, whilst the areas corresponding to the green and blue filter segments will be opaque.

On placing this reversed film in a projector, the lens of which is fitted with a banded filter similar to the taking filter, light on its way from the lamp to the screen retraces

its original path—it penetrates the transparent areas corresponding to the red record, escaping to the screen through the red segment of the filter. Since those portions of the emulsion on which the green and blue segments were imaged are now opaque, no light can pass through these regions to reach the screen via the green and blue segments. Thus, only red light will be transmitted to the screen. The same arguments apply for all colours. In the case of yellow, for example, the red and green areas would transmit, and

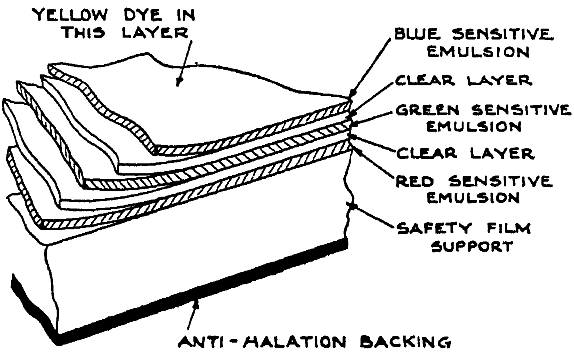


FIG. 42. KODACHROME COLOUR FILM.

the blue be covered up; white would be obtained when all sections of the filter transmitted fully, whilst for black none of them would transmit light.

As no really successful method of copying such lenticular films has as yet been discovered, and as, moreover, a very considerable amount of light is required for their projection, the processes are at present only of interest to the amateur.

Dufaycolor. This mosaic screen process is also available as 16 mm. film, and, although only introduced in 1934, has rapidly attained considerable popularity with amateurs. It has the advantage of requiring no special additions to the camera or projector, and the exposures required are considerably less than with the lenticular systems—a point of considerable importance in England, where the lenticular systems require midsummer sunshine for proper exposure.

Kodachrome is the only three-colour subtractive process as yet available as sub-standard film. Kodachrome film is built up of three separate emulsion layers coated in succession on one support. The layer nearest the film base is panchromatic

emulsion sensitive to red light. Above this and separated from it by a very thin coat of gelatine is an orthochromatic emulsion sensitive to green light, whilst the top layer is a non-colour sensitized emulsion which therefore only responds to blue rays. When this film is exposed in the camera the blue rays proceeding from the subject record on the top layer, the green rays on the middle layer, while the red rays pass through both these layers and affect only the bottom emulsion. The film is developed and reversed to a black-and-white positive in the normal manner. It then passes through a series of tanks in which the following operations occur. (1) All three images are toned blue-green. (2) The two top images are bleached and toned pink, the underlying blue layer not being attacked because the bleaching and toning solutions are only applied for sufficient time to allow them to penetrate the two top layers. (3) The outermost pink layer is re-bleached and toned yellow, and again the manipulations are such that these solutions only affect this outermost layer. The special form of toning employed is called 'colour development'. It depends on the fact that when developers reduce silver bromide they are themselves oxidized. In the case of pyrogallol the oxidized product is an insoluble yellow-brown colour which remains as a stain image when the silver image is bleached away (page 82). Special developing agents whose oxidation products are blue-green, magenta, and yellow respectively are used in Kodachrome processing.

The film ready for projection, therefore, carries a subtractive colour image built up of three layers coloured blue, pink, and yellow, the subtractive primary colours. Here again, no additional equipment is necessary, and the working speed is of the same order as the slower varieties of black-and-white kine-film.

CHAPTER XII

THE CAMERA CANNOT LIE (?)

'The sole perfection which modern civilization attains is a mechanical one, machines are splendid and flawless, but the life which serves them, or is served by them, is neither superb nor brilliant, nor more perfect nor more graceful; nor is the work of the machines perfect; only they, the machines, are like gods.' KAREL CAPEK.

'The Camera cannot lie.' W. E. GLADSTONE, in 1896.

'What is truth?' PILATE.

'HOW many steps are there supposed to be to the monument?' asked a visitor to London. 'Three hundred and forty-five and there 's no supposition about it,' replied the attendant.

Most of the striking advances in observational scientific investigations made in the twentieth century have come from the knowledge that the camera gives just this sort of answer to a properly asked question; and yet the statement, 'The camera cannot lie', is frequently claimed to be the biggest lie in photography.

To try to catalogue all the uses and abuses of photography is about as useful as an attempt at setting down all the applications of writing and printing, but before proceeding to examine the significance of the (?) in the title to this chapter we must review, however sketchily, the nature of the evidence upon which the camera's reputation for truthfulness is based, and in doing so we will take the opportunity of glancing at sundry applications of photography which could not conveniently be dealt with in earlier chapters.

As a weapon of research, photography's function is twofold: it is employed either as a means for recording phenomena, or else, as is generally the case, as a means of making a quantitative record of intensity or spacial effects which can be used for subsequent accurate measurement.

The simplest application of the camera in the first connexion is the straightforward photography of places or events. No eye-witness account retailed from memory can compare in truthfulness and accuracy with a photograph. You may have heard the story of the professor of biology who, during a lecture, produced a jar into which he dipped a finger. He then inserted his finger into his mouth and, passing the jar round, invited the students to follow his

example. When they had all sampled the evil-tasting contents he explained to such of them as still felt well enough to listen that the finger he had licked was not the one he had dipped into the jar! He then proceeded to reprove them for their faulty powers of observation, to which he attributed the slow progress they were making with their dissections. 'Yesterday's work was disgraceful, and in order that you can see how exactly a properly dissected frog should look, I have brought an excellent specimen which I myself dissected last night.' Producing from his pocket a small packet, he unwrapped it, disclosing a hard-boiled egg, two plums, and some bread and butter. The Professor stared at the parcel dumbfounded. 'But, surely,' he mumbled, 'I ate my lunch!'

The moral is that the unaided eye is not always a trustworthy instrument, while the interpretations placed upon a fleeting image recalled from memory are often wide of the mark.

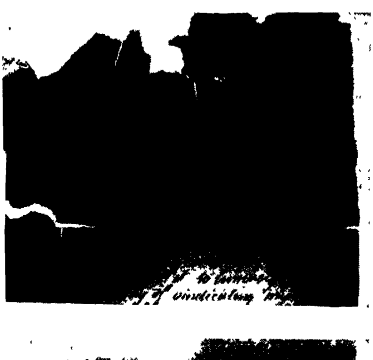
Record Photography. The photograph of Mount Everest is a typical example of a record photograph (Plate 12). Had the airmen brought back a water-colour drawing, however carefully done, we should make quite conscious reservations in accepting as an actual fact the curious appearance of the mountain. Indeed, as art grows more sophisticated it grows less useful for record purposes, and while modern paintings may be successful in conveying to the initiated the emotions of the artist as he gazes upon Nature, they convey very little else.

An interesting application of record photography in which amateurs are playing a leading part is research into weather prediction. Our weather is largely dependent upon the air currents at different heights above the earth, and the movements and shapes of clouds that float in these currents provide visible evidence as to their existence, direction, velocity, and nature. The 'deep depressions' which appear to constitute Iceland's main export to the British Isles consist, for example, of gigantic eddies some 500 miles in diameter into which air is being drawn from the surrounding high-pressure areas. Clouds will delineate the shape of the eddy, and a continued series of photographs of the clouds taken from the same position will tell us its history and so add to the evidence which is gradually being accumulated in support of meteorological theories. Theories in weather prediction, unlike the theories of astrologers who

End of a revolver cartridge bearing the 'thumb print' of the weapon from which it was fired. The tiny scratches and irregularities on the striker hammer are recorded as corresponding marks on the cap of the case *Courtesy of David Charles*

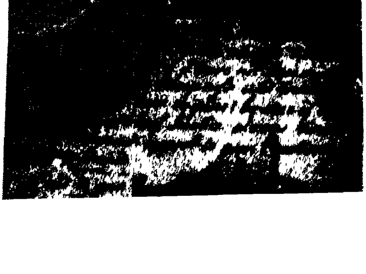
X-ray of human leg showing local thickening where a fracture has knitted together

Courtesy of Ilford Ltd.



Two methods of deciphering a charred document. *Left:* Ordinary photograph. *Below, left:* Infra-red photograph. *Below, right:* Artificial image obtained by 40 days' contact with a photographic plate. Plate fogged by emanation from charred paper; protected from fogging by ink

Courtesy of Dr. L. Bendikson



pretend to predict the future from a study of the planets, depend for their confirmation upon the facts of observation, and accordingly an increasing number of international surveys of the sky are being undertaken. The whole of the visible sky at any one place can be covered by five photographs taken with an ordinary camera pointed north, south, east, west, and upwards, and in 1934 the French Meteorological Service enlisted the co-operation of many thousands of amateur photographers scattered over the whole of Europe to take such photographs at stated times on certain days. As a result, it was possible to prepare cloud maps covering the whole of Europe. When a sufficient number of such surveys have been undertaken we shall at least have some new and dependable information which may help us towards an understanding of the causes of the weather.

Straightforward photography with an ordinary camera is used in innumerable ways to provide impartial evidence of changes that take place with the passage of time. Plate 36 shows a typical example.

Sometimes, as in the reading of meters or the photography of cheques passing through a bank, the record is made on sub-standard kine-film. Not only do such kine-films provide a convenient and unquestioned record, but they enable large masses of material to be recorded in very small space. In large firms and reference libraries this latter consideration is becoming of increasing importance, and microphotographic books have now materialized. A special small projector is made for use with these film books and can be used on the ordinary library table. Some idea of the economy in space will be gathered from the calculation that one cubic meter of space would be sufficient to store the equivalent of eight thousand 300-page books. If it was necessary, the storage space required could be considerably smaller. Thus, during the siege of Paris a message was dispatched by pigeon post in which 32,000 words were recorded by photographic reduction within an area of three square inches. By using an almost grainless emulsion even this startling reduction can be exceeded (Plate 37).

Proceeding to the other extreme, the camera has largely replaced the artist's drawing of subjects seen under the microscope. Not entirely, however, because the literal accuracy with which it records every detail visible on the microscope slide is sometimes a disadvantage. When

properly made the photomicrograph will be more scientifically correct, but it is a characteristic of the camera record that it is quite undiscriminating, and it is unable to exclude non-essential and possibly confusing detail and, for teaching and demonstration purposes, the artist's less accurate but simplified drawing is sometimes preferable.

Plate 39 (Diatoms) is a typical photomicrograph of the unpleasant scum that is found floating on the surface of stagnant ponds. The use of photography in connexion with the studies of water-supply is growing rapidly, and the Metropolitan Water Board laboratories are making increasing use of photographic records which enable them to demonstrate, not merely assert, what the condition of the water-supply is from time to time.

So far we have considered a few applications of ordinary cameras to the purpose of scientific record. But the value of the camera as a recording instrument is considerably extended when it has been specially designed for a particular job. It will inform us of facts which, without its aid, might never be known, and its eye will work efficiently under conditions where the most inquisitive of human eyes are useless. As a typical example, consider what it is that happens when a stone is thrown full at an approaching railway engine and rebounds. At the moment prior to impact the stone is moving in one direction, and immediately subsequent to impact its motion has been reversed. Just at the moment of impact it must have been momentarily at rest, but it was then in contact with the engine. Was the moving engine at rest?

On Plate 37 a photograph of a golf ball at the moment of impact illustrates the use of the camera to record fleeting incidents for subsequent examination, and provides the solution—the stone is elastic, and the moving engine is able to remain in contact with the stone at rest during the latter's momentary deformation.

Other interesting records of events too transient for normal examination are shown on Plates 13, 34, 35, and 37; while at the top of Plate 40 is a biographical series of flame snapshots taken at small consecutive intervals on the same plate by Dr. C. de C. Ellis. To the eye the flame is merely a shadowy, luminous shell. Such photographs enable us to study its structure. This photograph, which shows five flames ignited at the same moment in a cylindrical tube,

proves that flames can exert a mutual pressure on each other. From the flame surface two winds move in opposite directions, the surface acting in the same manner as a watershed; and the existence of stationary surge junctions between the flames, with consequent deformation of their original spherical shape, is clearly seen. The second photograph on Plate 40 shows a flame started in a vessel containing an excess of fuel over air and communicating by a hole with the atmosphere. When the air inside is used up the atmosphere burns back into the sphere, this later flame oscillating backwards and forwards, causing what looks like a crenellated luminous foam.

Below, on the other hand, is a photograph of Copernicus, a mountain on the moon. Those who are tempted to say that Dr. Ellis's flame photographs are more like the moon than this one, and that the camera is therefore lying, should remember that the scientists who made these photographs can easily distinguish between them!

Astronomy. The astronomer makes use of another valuable characteristic of the photographic plate, namely, its ability to integrate the effect of a faint light over long periods. Stars visible to the eye through the most powerful telescope are only a fraction of those that will record on a photographic plate. The planet Pluto was discovered photographically after mathematicians had predicted its existence.

If photographs are taken of the night sky it is found that in one direction more and more stars are recorded as exposure lengthens, whereas, in the opposite direction, the number of stars recorded reaches a limit. It is on observations such as these that astronomers base their suggestion that the solar system is situated relatively near one edge of the universe rather than at its centre.

The faith of the astronomer in the accuracy of the photographic record is little short of staggering. His estimates of the magnitude, brightness, speed, composition, and mass of stars—the size of the universe itself—are based upon spacial and density measurements of photographic plates.

A typical example is the astronomical confirmation of Einstein's theory of relativity. When a ray of light passes sufficiently close to a massive object its path is deflected, and the amount of the deflection in the case of light from a star passing close to the sun should be, according to Einstein, twice that suggested by pre-relativity theories.

During the eclipse of 1919 it was possible to photograph stars whose light on their journey to earth passed the eclipsed sun at grazing incidence; their relative displacement was determined by comparison with photographs of the same groups taken at night, and Einstein's prediction was confirmed.

Because the photographic emulsion is itself a work of art it is sometimes suggested that the evidence it supplies, when used as a scientific instrument, should be regarded with reserve. It is true that as yet we have only the glimmerings of an idea as to what happens to the emulsion when light strikes it. The density and even the size and shape of the image finally obtained depend upon the amount of exposure and the nature of the chemical treatment which follows. Emulsions with identical characteristics from batch to batch are still unattainable, and batches still go wrong for no apparent reason.

On the other hand, one does not need to understand how the eye works in order to be able to draw deductions from what one sees.

Reliance on measurements such as those mentioned presupposes that all possible disturbing factors are satisfactorily disposed of. The silver image is embedded in gelatine, and elaborate precautions must be taken to prevent distortion during manipulation. Thus, the over-exposed corona might have resulted in a local deformation of gelatine. Dust in the emulsion may give rise to 'extra stars'. Thin spots in the emulsion may upset density determinations, and so on. Even supposing these defects were of sufficient magnitude to nullify accurate measurements of spacial or density records, the camera could still be used as a precision instrument by basing deductions on the differences observable between photographic records made at different time intervals.

In 1878 an argument arose in California as to whether a trotting horse at any stage of its movement had all four feet off the ground at the same moment. In an attempt to settle the matter a Mr. Muybridge arranged a battery of cameras along one side of a corridor with black cotton threads stretching from the shutter release of each across the corridor. A trotting horse driven down the corridor automatically released the shutter of each camera as it passed, and in this way a number of records in which every stage in

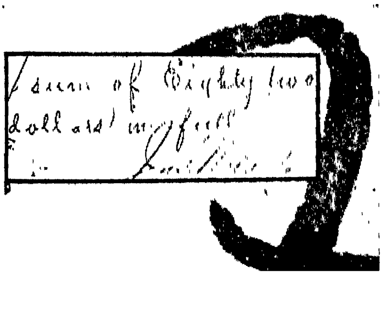
The cliffs of Dover from the coast of France: a panoramic view across the English Channel *Courtesy of The Times*

(*a*) Taken on an ordinary plate

(*b*) Taken by infra-red light on an infra-red sensitive plate

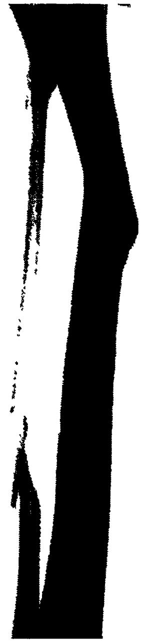
Photographs of a negro, ancestry unknown

Courtesy of Olaf Bloch, F.I.C., Hon. F.R.P.S., and Ilford Ltd.

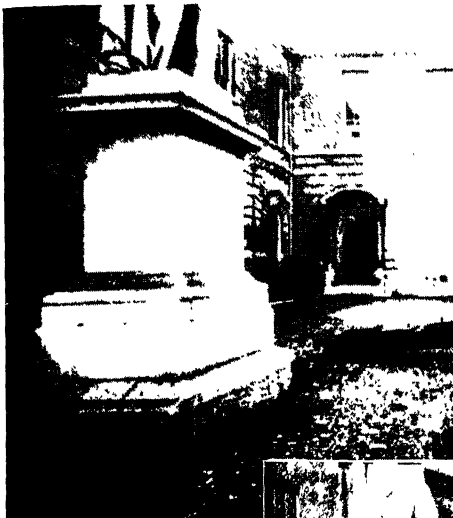


'Full' written over 'l'

Typewriting over ink stroke.
Reproduced by courtesy of W. M. Webb and Blackie & Son, Ltd. (' Photography as a Scientific Instrument')



X-ray photo—side view—
of leg shown in Plate 43
Courtesy of Ilford Ltd.

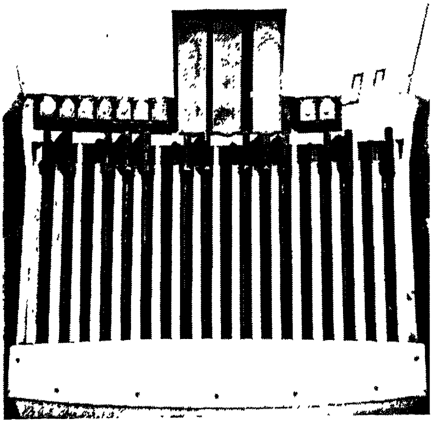


An example of distortion. This picture and the one below were taken from the same point of view. The camera was not moved—

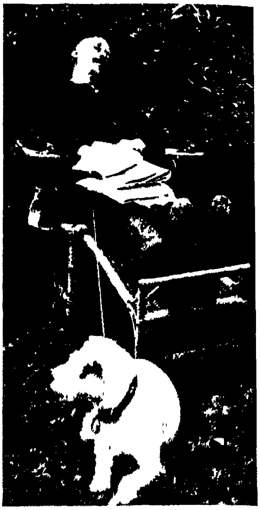
But the plate was swung to a different angle for this exposure

Courtesy of J. F. Young

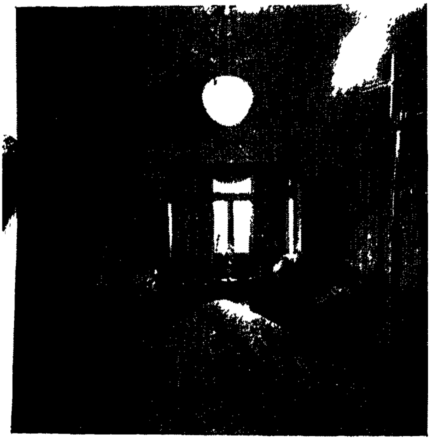
Not a catastrophe: merely



Organ Pedals *Courtesy of David Charles*

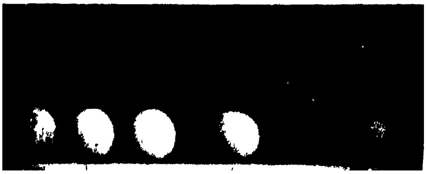


Distortion of perspective owing to use of too short a focus lens



Interior showing curvilinear distortion

Courtesy of David Charles



the horse's movement was shown was collected. The photographs did something more than prove that a trotting horse *does* at times have all four feet in the air—they crystallized the vague thoughts that were beginning to stir in men's minds as to the possibility of kinematography.

We have already referred to the value of kinematography as a means of changing the time scale so that actions too slow to be seen in life, such as the growth of plants, or too fast, such as the splash of a drop of liquid, can be projected on to the screen at such a rate that the eye is able to see and the mind to comprehend. Such methods of analysing movement have provided information of the most startingly diverse character. Thus, by photographing daily the changing shapes of an interference film between water, whose level is always perpendicular to the line passing through the centre of the earth, and a glass plate which, perforce, remained parallel to the earth's surface, the rigidity of the earth has been calculated. It appears from this work that the earth is practically as rigid as would be a steel ball of the same size.

In considering statements such as this we must, of course, bear in mind that they are inferences deduced from the photographic record, and it is always possible that the inferences are mistaken. On the other hand, the evidence provided by a photograph frequently does not need interpretation for its significance to be obvious.

In a recent dispute it was contended by the Bricklayers' Union that although a suburb of London (*a*) was outside the fifteen miles' radius, nevertheless the London scale of wages should apply, because extensive building in recent years had made the district an integral part of the City. They cited another suburb (*b*) in which, although outside the London area, the London scale was in force. Extended litigation was avoided by the production by the Master Builders of the aerial photographs on Plate 40, which showed conclusively that the district (*a*) could not be considered part of London, whereas (*b*) obviously was.

In addition to settling obvious points such as these, aerial photographs have drawn attention to subtle features of the landscape which had previously escaped notice. Curiously regular markings on aerial photographs of Stonehenge were found to be due to small variations in the colour or height of bands across cornfields, and to small contours in the land of no significance when viewed from earth's level. They

have subsequently been shown to mark the site of roads of ancient origin. The disturbance of the soil by the old, filled-in earthworks brings about subtle changes in the vegetation grown on it whose existence was not suspected until aerial photographs were examined (Plate 42).

In King John's time the land surrounding the Wash was a huge marsh traversed by a few firm roads, along one of which his retinue probably fled. Aerial photographs have revealed the site of these roads, and optimists are considering a treasure hunt.

We saw in Chapter X that the ability of the camera to draw attention to evidence not detected by normal methods of observation has now been considerably enhanced by the extension of emulsion sensitivity to regions of the spectrum not normally visible. The visible spectrum is from 4,000 to 7,000 Å.U., whereas the photographic spectrum extends from 1,000 to 12,000 Å.U. The greater penetrability of X-rays enables us to detect and record, by photography, defects in opaque structures. On Plate 43 is a typical example, an X-ray photograph of the bones in a human leg. At some time previous to the photograph the tibia was fractured, and the bone is locally enlarged where the ends have knit together. The owner of the leg was convinced that the bone was still broken, but the photograph proves that this is not the case.

The smaller scattering of infra-red rays has already proved its value in eliminating the effect of haze in long-distance photography. As a result, the camera can 'see' with comparative ease across the English Channel (Plate 44) or under our skins. Not only will the infra-red photograph of a clean-shaven man show the beard below the skin, but in the case of the negro (Plate 44) reveals distinctly Mongolian characteristics; and the possible application of infra-red photography to ethnological research is now being investigated.

The Camera as Detective. The ability to record and emphasize subtle differences of tint, shape, &c., results in the camera assuming the role of detective, as well as expert witness. It has almost completely replaced chemical tests as a method of detecting forgeries, while the photographic super-imposition of an original and suspected signature will demonstrate forgery by tracing to a jury, in an infinitely more convincing manner than a series of tedious measurement comparisons. The photomicrograph (Plate 44) proves

that the word 'full' was written after the signature, for it reveals clearly that the ink has run into the downstroke of the letter *j*. Similarly, it is obvious from inspection of the photomicrograph on Plate 45 that the writing is over the type matter. And yet, as the superscription clearly states, this was not the case! On inquiry we find that the ink-stroke was in a colour that did not record photographically as strongly as the typewriting.

It is true that a photographer, aware of the differing colour-sensitivity of the photographic plate and the human eye, might not have been deceived by this photograph, but Dr. Ainsworth Mitchell, the handwriting expert, recently drew attention to an even more striking example. A photomicrograph was sent to him, from the appearance of which it seemed obvious that an erasure had been made, and his opinion was asked whether the photograph proved that this was the case. He insisted on examining the original document for himself, and found no trace whatever of an erasure. It subsequently transpired that the photographer who had made the photomicrograph had kept the document flat by a piece of glass which had minute scratches on its surface in the neighbourhood of the signature. In the photograph the glass was, of course, invisible, but the shadows of the scratches remained and were responsible for the suspicious looking nature of the signature.

We are brought up with a jerk. We have been going too fast. Let us make a hasty survey of our conclusions to date and undo the damage where possible. We had better not bother about the forgers—it is too late anyhow, and would be unpleasant for us if they were in prison because of our unwise enthusiasm. They are probably quite happy where they are, busily engaged in writing their life stories for the Sunday Press.

But there is that man whose leg we X-rayed (Plate 44). He was sure that it was broken and we, after examining the X-ray photograph, were just as sure that it was not. Let us re-photograph it from a different position. But this is dreadful! The man's leg *is* broken (Plate 45).

We will proceed more cautiously and confine our camera to the recording of the simplest and most easily interpreted events. The value of the photographs on Plates 12 and 45, for example, in which a chronometer and the end of a race are photographed on the same plate, is obvious. Recently it has

been suggested that cameras should be built into the roofs of motor-cars, the shutter being operated when the brake is applied violently. In this way a record of emergencies which necessitate sudden braking will be made, and photographs such as Plate 46 (bottom) may find their way into motor accident cases!

Again, we are tempted to say that the camera has lied, although this is not the case. All photographic results are due to the effect of unchanging laws of nature, but we may be misled by a photograph just as we can be misled by a legal document by reason of our inability to interpret it. That a photograph always represents facts and nothing else but facts is its chief characteristic, but we are often led into drawing wrong inferences from the facts owing to the manner of their presentation.

In pictorial representation a distant object is shown on a smaller scale than a nearer object, and this must be so because as any object approaches the eye it hides an increasing extent of the view beyond it. But this gradation of scale can appear as though carried to excess when a perspective is examined from a view-point other than its own. If we were to examine the individual cars of this print in an apparatus which obliged us to look at them with one eye from the correct position, the suggestion of exaggeration would disappear.[1]

The upper two photographs on Plate 46 provide an excellent example of the misleading impression created by distortion. In this case the camera-back was swung to a different angle for the second exposure. As a result, the rays that formed the second image struck the plate at a more oblique angle. Such distortions do not detract from the camera's trustworthiness. They are the simple results of the conditions under which the camera was used, and were produced in accordance with very definite laws. Were this not the case, and were these laws not properly understood, it would obviously be impossible to produce the accurately contoured maps now prepared from aeroplane photographs. The importance for correct interpretation of knowing exactly the conditions under which a photograph is taken is well shown on Plate 47 (top) of organ foot pedals. The closing together of the receding pedals, due to perspective, is exactly

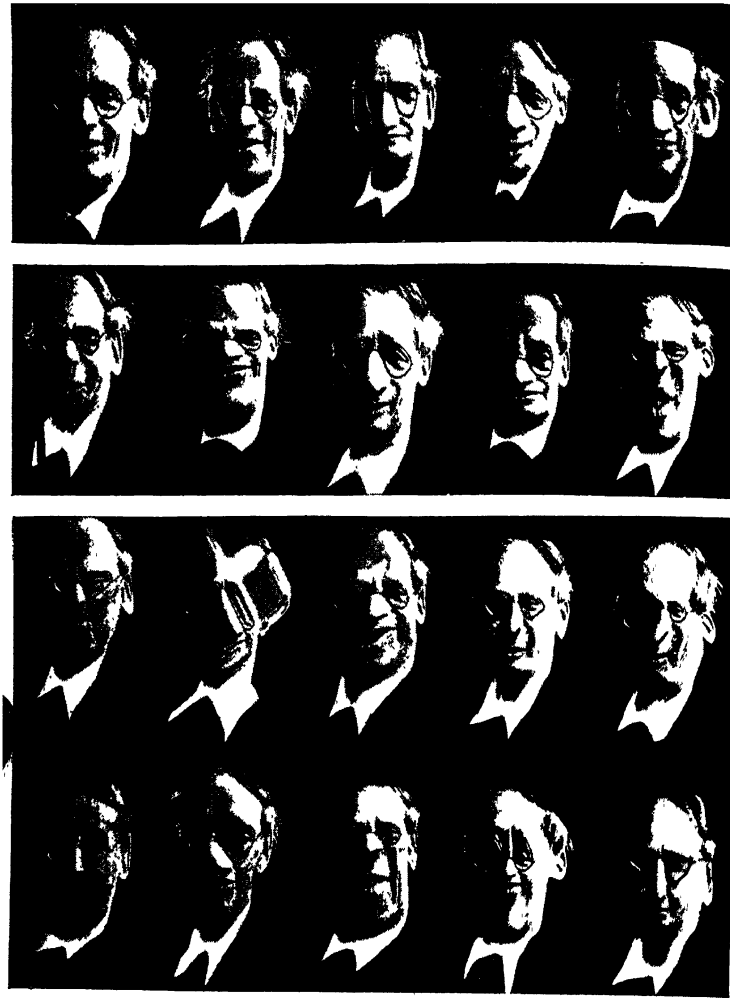
[1] For example, examine the man in the chair on Plate 47 with one eye from a distance of four inches.

After 'Wrecking'

Before 'Wrecking'

Courtesy of Charles Wormald, F.R.P.S.

An example of faking by combination printing from several negatives



Caricatures produced from one print by means of the late Herbert G. Ponting's Variable Controllable Distortograph. The 'parent' photograph from which the others were produced is in the top left-hand corner

cancelled by the spreading apart of the pedals, which were actually arranged in the usual fan shape.

The production by Mr. Wormald of the top print on Plate 48 from the photograph below it is in a different category. Clever retouching and combination printing certainly result in a lie being told, but the lie is not the camera's.

With scissors and paste the title of this chapter could be altered from 'The camera cannot lie (?)' to 'A mere hen can cit (?) a lot', but it would not be fair to claim that therefore we are now discussing the meaning (if any) of such a sentence.

Nevertheless, it is obvious by now that we cannot accept a photograph, however convincing, at its face value. Even when we know there has been no deliberate falsification, anomalous results are obtainable because of imperfection in the instrument—more particularly in the lens.

Curvilinear distortion, for example, is the condition which leads to the representation of a rectangular object with its four boundaries bulging out like the sides of a barrel, or inwards like the contours of a pin-cushion. The distortion is usually of such small dimensions as to be negligible, because the wide angle that the whole of the lens would embrace is cut off by the diaphragm which is some distance in front of the lens. If, however, we bring the stop close to the lens so as to use the whole available field of view, the distortion may become serious (Plate 47).

If a row of tennis balls is photographed with a single lens with a diaphragm well in front, and then re-photographed with the diaphragm well in front of the lens, the distance apart of the balls as recorded on the plate varies at the edges, being nearer to the centre with the stop before the lens and farther away with the stop behind (Fig. 43 and Plate 47). By placing the diaphragm between the lens elements we make these two errors annul each other.

The Variable Distortograph. A good lens is a mixture of faults of opposite kinds carefully balanced so that each aberration is neutralized by a corresponding one of opposite character, and by deliberately upsetting the nice balance of opposing faults in a lens system the late Mr. Herbert Ponting produced an ingenious instrument which he called the Variable Distortograph. The instrument was primarily designed for converting ordinary kine-film records into distorted caricatures which could be either uproariously funny

or sinister nightmares. Used with discretion, this device may prove a wonderful addition to the kine-technician's box of tricks.

Some of the distortions which can be produced by exploiting the peculiarities of unconventionally shaped lenses are shown in Plate 49. The photograph in the top left-hand corner is of Mr. Olaf Bloch, a past President of the Royal Photographic Society who is doing pioneer work on the special emulsions required for astronomy, atomic physics,

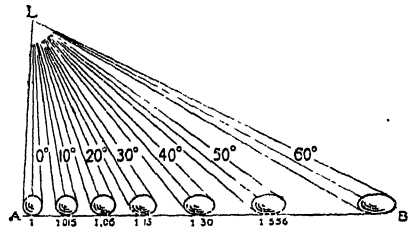


FIG. 43. Illustrating perspective views of spheres seen at different angles. The actual photograph is shown on Plate 47, and it will be seen from this diagram that the distortion is due to the 'flatness' of the plate. If the plate was curved up at its edges, so that B was the same distance from the lens as A, the distortion would disappear.

and infra-red work. It was Mr. Bloch who drew attention to the possibility of infra-red photography being interesting ethnologically, but ethnologists are doubtful whether this is actually the case, and it may be that the Mongolian appearance of the negro on Plate 44 is just as meaningless as the suggestion that the remaining pictures on Plate 49 have any significance as a revelation of Mr. Bloch's versatile nature!

Even if we had a perfect lens which cast an image as closely resembling the scene in front of the camera as could conceivably be wished, it must be remembered that the emulsion would not necessarily respond to the light falling on it in a manner comparable with the stimulus received by the eye.

Very few photographs show the correct tonal relationships of nature from one end of the scale to the other; and by appropriate filtering, the apparent luminosities of many of the colours in a scene can be represented as the converse

of the visual impression. The processing which the negative receives can be made to increase such deceptions. Thus, a photograph apparently showing a foggy day does not prove that there was a fog—the negative might have been under-exposed and under-developed—or exposed through a filter which transmitted ultra-violet preferentially to visible light. Alternatively, a clear distinct photograph does not prove that objects seen in the print were visible to the eye—since the negative may have been made on an infra-red sensitive emulsion.

Finally, of course, it must be remembered that the success of a deception made possible by photography may depend upon the actual truthfulness of the photograph, as when the grain of an expensive wood is reproduced as a photographic veneer on metal or cheap wood.

Nevertheless, it remains true that, in photography, errors are nothing more than the natural result of the procedure that leads to them. They are not random, as in an artist's drawing, but are strictly definable if the conditions under which the photographs were taken are known. The photograph always has a definite relationship to the thing photographed, and because its work is free from personality or bias the camera cannot lie—or can it?

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